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E-fools: why e-fuels in cars make no economic or environmental sense

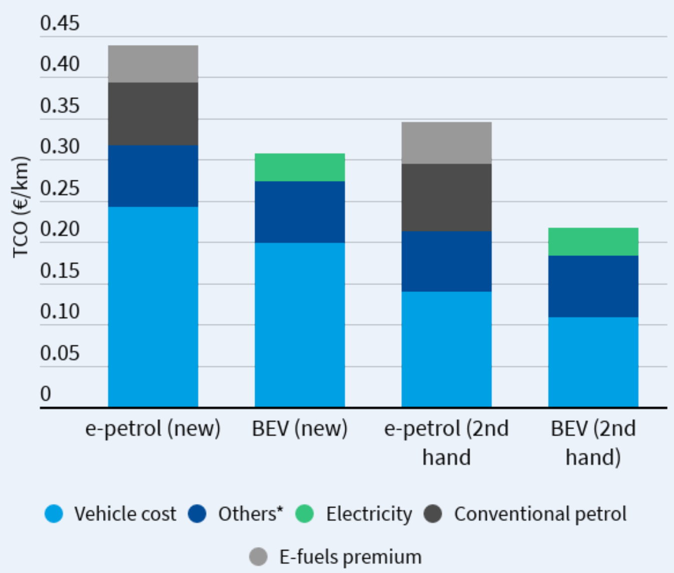
April 2021

Summary

With the review of the EU CO_2 emissions standards for cars and vans scheduled for June 2021, some, notably the oil and gas industry and automotive suppliers, are advocating adding CO_2 credits for advanced biofuels and synthetic fuels into the vehicle standards. T&E's new analysis shows why this is not credible— neither from an environmental nor from an economic point of view.

Out of the Green Deal compatible technologies to decarbonise cars - sustainable batteries, green hydrogen and renewable e-fuels - electrifying cars directly using batteries is by far the most efficient zero emissions pathway to decarbonise cars. Driving a car on e-fuels produced from renewable electricity would require close to five times more energy than when driving a battery electric vehicle (BEV). Additional analysis in this paper now shows how both on cost and lifecycle emissions BEVs strongly outperform e-fuel powered petrol cars.

Economic perspective: e-fuels would place a cost burden on both the economy and drivers



T&E's **Total Cost of Ownership** (TCO) **analysis** shows that the very high costs of operating a conventional **vehicle running on e-fuels would place a cost burden on the average European driver**. For both new and second hand cars in 2030, the TCO premium for running a car on e-petrol compared to a BEV is €10,000, or 43% more expensive for an average driver. Critically, the TCO of running an existing petrol car on e-fuels would still be 10% higher than buying a new battery electric car, making e-fuels an unaffordable and unsuitable option for the existing fleet.

E-fuels would also be **the most costly CO_2 compliance route for carmakers**. It would cost carmakers around €10,000 in fuel credits for the amount of synthetic petrol needed to compensate for the emissions of an efficient petrol car placed on the market in 2030. On the other hand, the cost of a BEV battery could plunge down to €3,000 by 2030— or more than three times less than what carmakers would pay for fuel credits— and with BEVs reaching cost parity with ICE in the mid 2020s, producing a battery electric vehicle rather than a petrol car will not require much additional investment. The e-fuel route would therefore put the competitiveness of the European automotive industry at risk as it would divert large investments away from the transition to emobility.

The higher compliance costs from e-fuels will eventually be passed on to the wider society leading to a less cost effective trajectory for our society and our economy as a whole. T&E shows that the total **additional cost of an e-fuel pathway would be five times higher compared to the electrification pathway**. The industry claims that producing e-fuels in Africa and importing them to the EU would lower the costs thanks to cheaper solar PV. In this paper, T&E assumes this most favourable case for e-fuels where these fuels would be available in 2030 and shows that the lost revenue for the EU economy could be around 10 times higher for the e-fuels pathway compared to domestically produced batteries from the early 2020s).

In brief, the idea of powering cars with e-fuels does not have economic credibility— neither from the drivers perspective, nor from the carmakers compliance angle or from the economy as a whole. **Allowing e-fuels credits would thus only increase the costs of decarbonisation and delay the inevitable transformation towards affordable electric mobility**.

Climate perspective: e-fuel environmental benefits are a mirage

Updated T&E lifecycle CO_2 analysis shows that **the average amount of CO_2 emitted by new BEVs powered by the EU electricity grid in 2030 is around 40% lower than for a petrol car running on the e-fuels** which meet the RED II sustainability criteria.

If electricity with the same carbon intensity is used to power the BEV and to produce the e-fuel (in line with RED II criteria), the battery car emits half as much as the comparable petrol car running on e-fuel. Conventional cars powered with e-fuels consistently emit more CO_2 than an equivalent BEV, including in Germany where such e-fuels are high on the agenda. **Using e-fuels to power conventional cars will provide considerably less climate benefits,** on top of requiring much more renewables.

Availability: e-fuels should not be diverted to cars where better alternatives exist

The limited availability of scalable sustainable fuels means that there is no scope to use renewable electricity inefficiently for the production of e-fuels for road transport where other more efficient, cleaner and cheaper solutions are available. Promoting even a limited use of synthetic hydrocarbons in road transport now will divert the manufacturing and supply chains from being targeted at sectors such as aviation, maritime or the heavy industry. This makes the transition harder to accomplish and could seriously delay the decarbonisation of the economy sectors which cannot use batteries to decarbonise.

Vehicles CO_2 regulations should not allow fuel credits

Adding e-fuels to the car CO_2 regulation would greatly weaken its effectiveness. Carmakers would be able to buy fuel credits instead of accelerating what they have direct control over: the efficiency and the electrification of their vehicle sales. The effectiveness would also be watered down when mixing different sectors (downstream transport vs. upstream fuels), already covered in effective sector-specific legislation. From the smart regulation point of view, such a complex compensation system would likely **undermine the credibility and enforceability of the regulation**.

The EU is at risk of making an untenable tactical blunder. Rewarding synthetic fuels under the cars CO_2 standard regulation is a bad idea- implementing this would delay electrification in road transport, prolong life of polluting engines and postpone the economy-wide decarbonisation by misallocating green electrons. With no e-fuels at scale in sight, and a surge in electric car sales, the e-fuels appear to be a Trojan Horse to keep combustion engines and demand for hydrocarbons alive. Politicians must not allow the transition to zero emissions mobility to slow down.

⇒ **There should be no CO_2 credits given to auto makers for either alternative or synthetic fuels used in road vehicles under the vehicle CO_2 regulations.**

Introduction

To achieve a European Green Deal objective of reaching climate-neutrality by 2050, the European Commission will propose the 'Fit for 55' legislative package to reduce emissions by at least 55% by 2030. As part of this package it will propose a revision of the cars and vans CO_2 emission standards in June 2021 in order to align cars and vans with the wider decarbonisation strategy.

Amidst the discussions on the upcoming revision of car CO_2 regulation, the idea to add credits for advanced and synthetic fuels into the EU vehicle CO_2 standards has resurfaced, heavily pushed by the oil and gas industry. Already in 2017 and 2018, during the last round of EU light duty and heavy duty CO_2 negotiations, the same industry had been unsuccessfully advocating to include such a mechanism in the regulation.

In May 2020, a study commissioned by the German economic ministry advocated for synthetic and advanced alternative fuels to be included into the regulation[1]. In November 2020, T&E highlighted the shortcomings of the study, showing that this approach was a bad idea and had no regulatory credibility[2].

In this paper, T&E goes further and provides a deeper economic and climate assessment of the implications of having conventional cars run on synthetic fuels, focusing on conventional cars running on e-petrol.

1. High costs for drivers

1.1 Quadrupling energy costs

Synthetic fuels -or e-fuels- are produced by combining hydrogen and carbon in order to create a hydrocarbon (like petrol or diesel) which can be used to propel a conventional petrol or diesel vehicle[3]. The hydrogen can be produced via electrolysis by splitting water into hydrogen and oxygen molecules while the carbon can be obtained via direct carbon capture.

Because of this energy intensive process, running a car on synthetic petrol is close to five times less efficient than powering a BEV through direct electrification[4]. The overall efficiency of the direct electrification pathway is 77% whereas it is 16% for petrol cars powered with synthetic fuels.

With more complex and energy intensive processes, also comes higher fuel costs and transportation costs. In 2030, **the energy cost to power an efficient petrol car running on synthetic fuels will be close to four times higher than for a BEV** (Figure 1). Depending on the extent to which the production cost of

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[1] Frontier Economics (2020), *Crediting system for renewable fuels in EU emission standards for road transport.* Link
[2] Transport & Environment (2020), *Why adding fuel credits to vehicle standards is a bad idea.* Link
[3] Only synthetic fuels produced from electricity will be considered in this paper.
[4] Transport & Environment (2020), *Electrofuels? Yes, we can … if we're efficient.* Link

e-fuels drops in the next decade, the energy cost would be in a range of 3.4 and 4.2 times higher (3.8 based on our central scenario) with synthetic fuels.

The industry claims that producing e-fuels in Africa and importing them to the EU would lower the costs thanks to cheaper solar PV[5]. In this paper, T&E assumes this most favourable case for e-fuels where these fuels would be available in 2030. However, T&E does not think it is realistic in the medium term because no certification, standards, infrastructure, or long-term contracts are in place yet. Furthermore, the additional costs from the handling and the distribution of the fuel from production to the consumer point could add costs which are not totally reflected here. Even in this most optimistic scenario, e-fuels remain much more expensive for the driver. T&E does not support or endorse this option but uses it here as a most optimistic case to debunk the fact the e-fuels can be cheaper thanks to imports. The assumptions are detailed in the info box below and in the Annex.

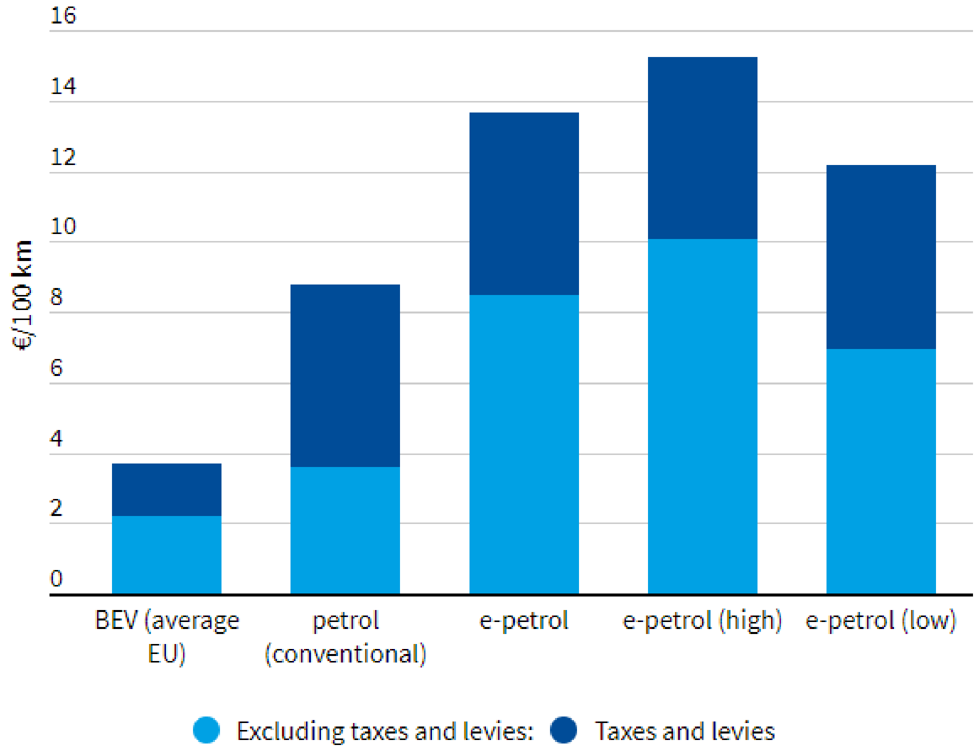


Figure 1: Energy cost comparison of electricity and liquid fuels for an average car(EU average)

For synthetic diesel fuel similar results are found (not shown here) with a range of energy costs being between 3.3 and 4.3 times higher (3.8 under the central assumption).

[5] See for example the eFuel Alliance : https://www.efuel-alliance.eu/de/efuels

Synthetic fuel cost assumptions

The Agora PtG/PtL calculator was used to calculate the levelised cost of electricity (LCOE) and the cost of synthetic e-petrol and e-diesel excluding taxes & levies based on the reference scenario.[6] The electricity generation and fuel production facilities are based on solar PV in North Africa (most optimistic assumption, not supported by T&E). The chosen weighted average cost of capital (WACC) is 6% and the method of CO_2-extraction is direct air-capture (DAC). Solar PV in North Africa was set at a load factor of 2,344 full-load hours per year. High-temperature electrolysis as well as FT-synthesis were set at 4,000 full-load hours and, thus, rely on temporary hydrogen storage.

The transport and distribution costs are based on Fasihi et al. and take into account transport via tanker vessels from North Africa (Algiers) to the Port of Hamburg and domestic distribution to the refuelling station via conventional tanker trucks.[7]

Overall production costs in 2030 are 1.3 €/L for e-petrol, which translates into a price of 2.3 €/L for the consumer once taxes, levies and transport are included (same final price for e-diesel). Taxes and levies are assumed to be the same as for fossil petrol in the EU27: 0.86€/L (2020 average).

1.2 High total costs of ownership (TCO)

Already today, the total cost of ownership (TCO) of a BEV is lower than the TCO of a comparable conventional car in more than ten European countries[8] and their economic case will only be strengthened in the next few years. Indeed, BEV prices will drop and are expected to reach upfront parity with ICEs in the mid 2020s (without subsidies)[9] thanks to decreasing battery costs (-60% between 2020 and 2030[10]) and improvements of manufacturing techniques, notably through integration and scale[11]. On the other hand, even in the optimistic scenario, e-fuel price will remain higher than today's conventional fuel price (as shown above).

New BEVs are one third cheaper than new petrol with e-fuel

As a result, the TCO of a BEV purchased in 2030 would be 30% lower than for new efficient petrol cars running on synthetic fuels. Both the vehicle cost and the fuel cost are expected to be lower for the

[6] Agora Verkehrswende et al. (2018). PtG/PtL calculator. Retrieved from https://www.agora-energiewende.de/en/publications/ptg-ptl-calculator/

[7] Fashihi et al. (2016). Techno-Economic Assessment of Power-to-Liquids (PtL) Fuels Production and Global Trading Based on Hybrid PV-Wind Power Plants. Retrieved from https://www.sciencedirect.com/science/article/pii/S1876610216310761, various pages.

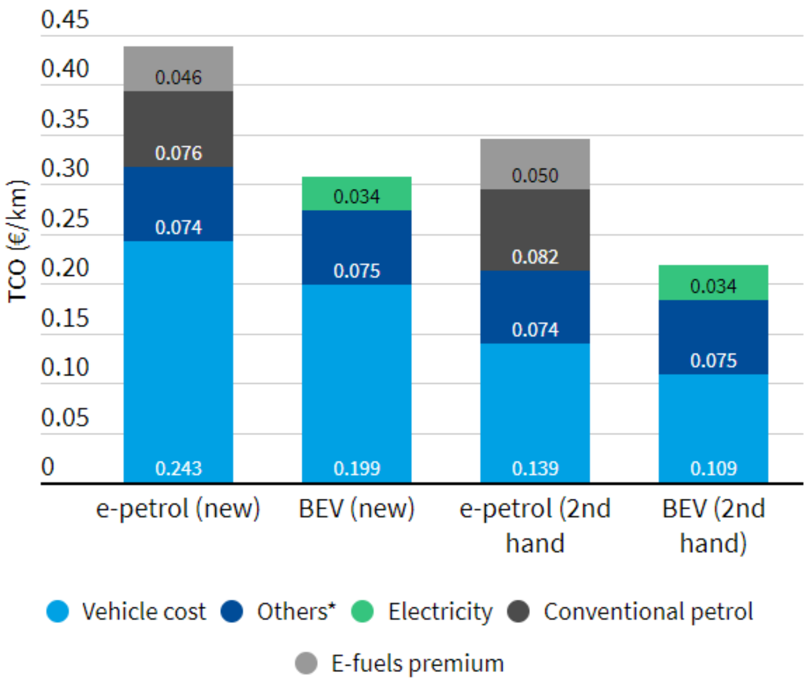
[8] Leaseplan calculates a lower TCO for BEVs in 11 countries out of 22 European countries. The 11 countries are: Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Norway, Portugal and the UK. Source: LeasePlan (2021), EV Readiness Index 2021. Link

[9] BNEF (2020), Electric Vehicle Outlook 2020. Link

[10] BNEF, March 5 2019, *A Behind the Scenes Take on Lithium-ion Battery Prices.* Link

[11] McKinsey (2019), *Making electric vehicles profitable* Link

BEV in 2030, which puts the e-petrol option in a position which would be untenable for the average driver. All assumptions are detailed in the Annex.



* Others include insurance, maintenance and cost of a private charger
TCO comparison for a medium car, based on European averages and 5 year ownership period. E-fuel cost: T&E calculations based on Agora Verkehrswende et al. (2018) and Fasihi et al. (2016).

Figure 2: TCO comparison BEV vs. ICE in 2030

After a 5 year ownership period, a driver buying a new petrol car and driving on e-petrol would spend an additional €10,000 than with a new BEV.

It is assumed here that the petrol car drives on 100% e-fuels, which would be the most expensive option for the driver. In reality, it is likely that e-fuels would be blended with overall fuel mix (including conventional fuel). However, the results presented above hold true even in the situation where e-fuels are blended. For example with a 50% e-fuel blend the 'e-fuel premium' in grey in Figure 2 would be cut by half and the BEV would be 26% cheaper instead of 30% cheaper.

New BEVs are still cheaper than 2nd hand petrol cars with e-fuel

The industry often puts forward the idea that synthetic fuels are an effective solution to decarbonise the existing car fleet stock. While it might be true that a car running on e-fuels produced from renewable energy, would emit less CO_2 than if it was running on fossil fuels (but still more than a BEV, see Section 3), a second hand petrol car running on e-fuels would still be very expensive when compared to 2nd hand BEV. Similarly to new cars, the premium for running a second hand car on e-petrol compared to a second hand BEV is also around €10,000. The ownership period (5 years) and distance driven (15,000 km per year) assumed here is the same for the first and second ownership period for a like-for-like comparison. In reality, older vehicles are driven less than new vehicles. This would reduce the fuel and electricity costs for both second hand vehicles in the figure.

Running a second hand petrol car is still 10% more expensive than buying a new BEV. This means that even buying a new BEV is still a cheaper solution for drivers than using an existing petrol car powered by e-fuels. This result is calculated with a first hand and a second hand car running the same distances over their ownership periods, which means the driver would have the same driving habit with a new or second hand car. Different mileages between the first and second hand owner can lead to different results.

In conclusion, new T&E TCO analysis shows that the very high costs of operating a conventional vehicle running on e-fuels would place a great burden on the average European driver effectively making this economic option implausible. Mobility costs for consumers would simply be too high.

2. Effects on our economy

2.1 E-fuels are the most costly compliance route for carmakers

Accounting for fuel credits under the car CO_2 emission standards would effectively allow carmakers to buy their way into compliance. Indeed, rather than improving the vehicle tailpipe emissions and shifting to zero emission mobility, OEMs could buy credits from fuel suppliers for synthetic fuel that are placed on the market. In this section, T&E shows that carmakers' 2030 compliance costs for placing an e-fuel powered conventional vehicle on the road are several times higher than those for BEVs.

Methodology: The cost of a synthetic fuel credit is calculated as the production cost premium of going from conventional petrol fuel (excluding taxes and levies) to renewable-based synthetic petrol. In order to compensate the emissions of a petrol car placed on the market and consider it as zero emission on paper, zero emission synthetic fuel credits equivalent to what the vehicle will consume over its whole lifetime are considered. This is compared to the cost of a battery in a BEV.

T&E shows that in 2030 it would **cost close to €10,000 in synthetic fuel credits to compensate for the emissions of an efficient petrol car placed on the market** (around €11,000 in 2025). On the other hand, we can compare this with the cost of a BEV battery, which would cost around €4,400 in the early 2020s and €3,000 in 2030, or between **two and three times less** than the price of the fuel credits calculated above.

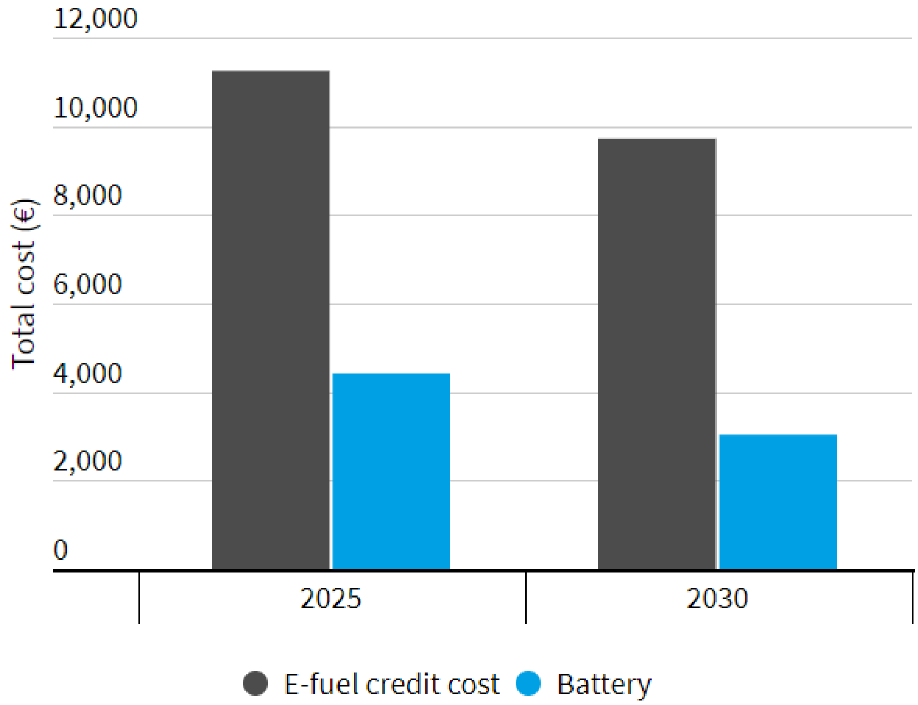


Figure 3: Comparison of e-fuel compliance route with battery price

In reality, the comparison between the cost of the efuel credits and the battery price is disingenuous, as **selling or producing a BEV will not require OEMs to pay any money upfront**. BEVs will reach production cost parity with ICEs in the mid 2020s. This implies that, all else being equal, in reality, the drivetrain of a BEV (battery, motor(s), and electronics) would not cost more than that of an ICE (engine, exhaust treatment, transmission). In 2030 the list price of BEVs is likely to be lower than for ICEs thanks to lower battery costs, optimised BEV platforms and economies of scale, which indicates that the compliance cost for an OEM for going for a BEV rather than a petrol could even be negative. Therefore, at this stage, it will not cost carmakers more to produce and sell a BEV rather than an ICE.

In short, as already shown by T&E in autumn of 2020[12], synthetic fuels are the least cost-effective path for carmakers. Complying using e-diesel and e-petrol credits raises compliance costs two-to-three-fold and these higher expenses made by carmakers would divert investments away from the emobility transition (e.g. in new BEV dedicated platforms or battery production) into the pockets of the oil and gas industries.

2.2 Social costs

The higher compliance costs for an efuels pathway will eventually be passed on to the wider society leading to a less cost effective decarbonisation trajectory for our society and our economy as a whole. In this section T&E shows that the total additional societal **cost of an e-fuel pathway would be five times higher compared to a BEV pathway**.

[12] Transport & Environment (2020), *Why adding fuel credits to vehicle standards is a bad idea.* Link

Both pathways are based on an increase in the ambition of the 2030 car CO_2 emission standards from the current 37.5% to a hypothetical 50% reduction. In the BEV scenario, the additional efforts are achieved by selling an extra 3 million BEVs in 2030 (on top of close to 4m BEV and 2m PHEV needed for the current 2030 target). In the hypothetical e-fuels pathway scenario, the compliance gap is bridged by only buying fuel credits to compensate the lifetime emissions from the fuel burnt by the same amount of petrol cars. When stacking up the vehicle sales in the 2020s, there is an additional 13 million BEVs in the vehicle stock in the BEV scenario. This comes on top of the 22 million BEVs and 15 million PHEVs on the road in 2030 needed to comply under the current targets. In the e-fuels pathway an additional 13 million petrol cars running on e-fuels in the e-fuel pathway are placed on the roads in the 2020s.

In the e-fuels scenario, the total production cost of the e-fuels needed for those 13 million petrol cars to be accounted as zero emission vehicles would be €230 billion up to 2030. On the other hand the additional battery costs to produce these 13 million BEVs is under €50 billion, or around five times less. The battery costs considered here are based on BNEF's forecast: 74 €/kWh in 2025 and 51 €/kWh in 2030[13], see Annex for more details.

Methodology

To understand to what extent the money spent on batteries or efuels would be spent overseas versus invested back into the European economy, T&E has made estimates of the share of the total spendings which are kept in the EU versus leaving the EU for the vehicles which are placed on the market up to 2030. As explained in Section 1.1, the most optimistic case for e-fuel costs are assumed in this paper (as advocated by the industry) where e-fuels would be produced and imported from Africa. The timeframe of the analysis looks at the 2020s, and includes the full lifetime costs of the e-petrol credits needed to fuel the petrol car. Although T&E deems it is unrealistic that e-fuels would be produced and imported from Africa in the 2020s, it was nonetheless assumed that small volumes of these e-fuels would be imported before the 2030s in order to carry out the full societal cost impact of this scenario. The e-fuel imports before 2030 actually only account for a limited share of the overall e-fuel imports needed to power the cars placed on the market in the 2020s over their lifetime. Indeed, the e-fuel consumed by the petrol cars before 2030 would account for around a quarter of the total e-fuel consumed over their lifetime, with less than 10% before 2027, and less than 2% before 2025.

Out of the total production cost of synthetic fuels, T&E assumes that only 30% would flow back in Europe (see Annex), thanks to the added value generated by the European fuels and hydrogen industry when selling the technology necessary for the overseas production. On the other hand, T&E assumes that around a third of the overall battery price does not create economic value in the EU (i.e. flows outside Europe). Indeed battery raw materials account for around a third of the overall battery price and with recycling and EU gigafactories, the industry will create economic value (hence jobs) in the EU. Conservatively, the economic benefits of primary supply of raw materials from European sources and recycling are not accounted for here (this would lead to lower reliance on primary raw materials from outside the EU).

Results

[13] Adjusted to higher battery prices in Europe compared to the global average up to 2030

Based on the above, T&E estimates that the economic value flowing outside of the EU in the BEV pathways is €16 billion while it would be close to €160 billion in the e-fuels pathway.

In brief, the total societal spendings in the BEV pathway scenario are around five times lower than in the e-fuels scenario but given a larger share of these costs would be spent on e-fuels imports, **the economic cost of lost revenue for the EU would be close to 10 times higher in the e-fuels pathway.**

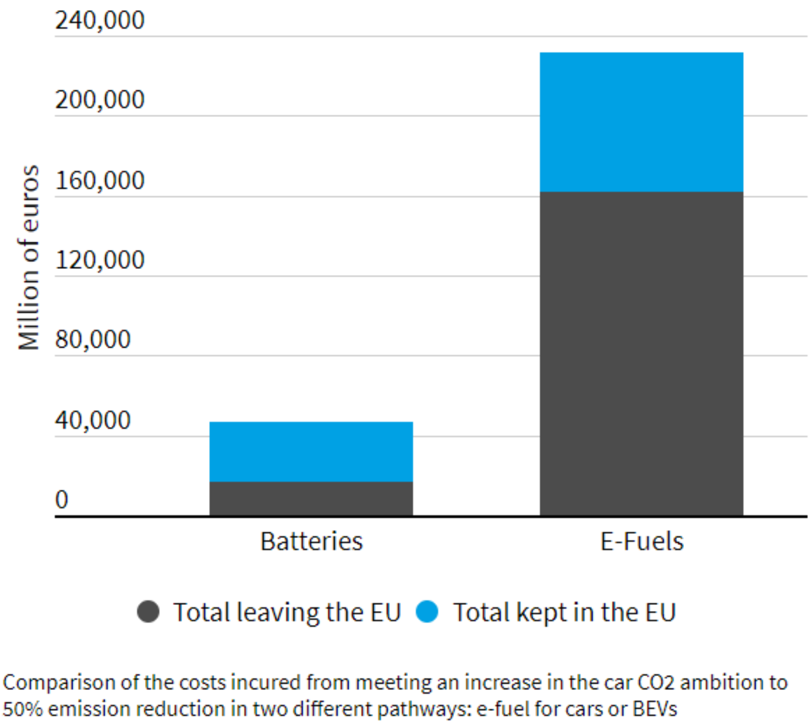


Figure 4: Societal costs: BEV vs. efuel pathways compared

Choosing to power cars with e-fuels means that European drivers and the EU economy as a whole would have to pay the big price and **send billions of euros abroad**, just like we do today for oil.

The conclusion is clear: the idea of powering cars with e-fuels doesn't have any economic credibility, neither from the driver perspective, nor from the OEMs compliance angle or from the economy as a whole. Allowing e-fuels credits would thus only increase the costs of the ongoing transformation towards electric mobility.

3. E-fuel powered cars emit much more CO_2 than battery electric cars

Synthetic fuels - which require a large amount of electricity to be produced - are only as clean as the electricity used to produce them. In this section T&E analysis shows that even under the new sustainability criteria laid out in the Renewable Energy Directive (RED) - which requires efuels to be produced from renewables to a very large extent- the climate impact of a petrol car running on e-fuels is much worse than for a BEV.

General LCA methodology

Throughout this section, the comparison is on lifecycle emissions of a new vehicle in 2030. The lifecycle analysis for the petrol cars powered by e-fuels is broken down in two steps: first the eligible e-fuels are determined with the RED II sustainability criteria (more details below), which is undertaken on a WTW basis. In other words, the RED II criteria are used to determine how much renewable electricity (counted as zero based on a WTW approach) is necessary to produce the efuel. Second, the lifecycle CO_2 emissions from the fuel production which meets the WTW sustainability criteria are calculated and plugged into T&E's EV LCA tool. The total amount of electricity consumed by the vehicles is calculated over this lifetime and lifecycle emissions of each electricity source is then accounted for based on respective lifecycle emissions factors from the IPCC. This lifecycle emission analysis thus provides a broader picture, including indirect emissions from the infrastructure for renewables (i.e. renewables are not zero emission) as well as other emissions from the production of the vehicle and the EV battery for example. For more details on EV LCA methodology, please see previous T&E report[14].

Methodology: GHG reduction from e-fuels under the RED II

The RED outlines a regulatory framework to ensure the sustainability of so-called renewable fuels of non-biological origin (RFNBOs) by requiring at least 70% greenhouse gas savings compared to their fossil fuel equivalent[15]. In effect, this implies that a high share of renewable electricity will be needed to meet this threshold. Around 90% of the electricity will have to come from renewables if a combination of electricity from renewables and gas is used. In the situation that grid electricity is used in 2030 to produce the e-fuel, the share of additional renewable electricity would still have to be around 70% (on top of the 55% renewables included in the 2030 electricity mix[16]). For a combination with gas generation with CCS the share of additional renewables would be similar - 67%. In this analysis T&E assumes that the 70% GHG reduction criteria for e-fuels is calculated based on WTW emissions emissions from energy sources (i.e. not lifecycle emissions, which means that renewables are counted as zero - no infrastructure related emissions). In this methodology we assume direct air capture of CO_2 and we do not consider the different point source possible (only the energy used to perform carbon capture and utilisation is accounted for).

In January 2021, T&E laid out detailed recommendations on what the minimum criteria for RFNBOs should be under the still-to-be-defined RED II methodology in order to ensure the sustainability of electrofuels[17]. Crucially it is key that the renewable electricity used needs to be produced from *additional* renewable sources: This would favour Power Purchase agreements in new and unsubsidised renewables

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[14] Transport & Environment (2020), *How clean are electric cars?* Link

[15] The European Commission has been tasked to adopt a delegated act by the end of 2021, on how to calculate the greenhouse gas savings of RFNBOs. Here, T&E conservatively assumes that the 70% reduction set by the European Commission is on the lifecycle emissions of the fuels produced.

[16] Source: ENSOE Ten Year Network Development Plan from 2020. For more see: Transport & Environment (2020), *How clean are electric cars?* Link

[17] Transport & Environment (2021), *Getting it right from the start: How to ensure the sustainability of electrofuels.* Link

projects rather than allowing for Guarantees of Origin which are not fit for purpose (no additionality, no temporal correlation, risk of double counting etc). Furthermore, the methodology should encourage non-fossil circular sources of carbon like direct air capture. Failing to promote atmospheric sources of carbon entails risks of lock-in of cheaper fossil sources of CO_2 from industrial sources.

Results: BEVs emit 38%-46% less CO_2 over their lifecycle

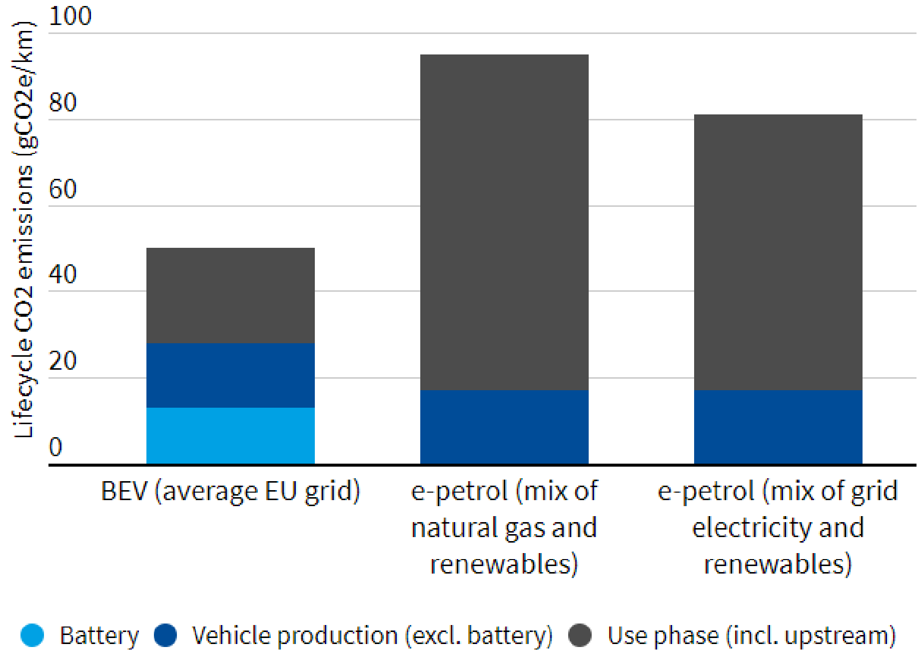
T&E has updated its lifecycle CO_2 analysis from the 2020 report 'How clean are electric cars?'[18] and associated tool (*transenv.eu/LCA*), to compare the lifecycle emissions of new BEVs with new petrol cars running on e-fuels in 2030.

Although the electric car has a 'carbon debt' when coming out of the factory gate due to the production of the battery, **the average total lifetime amount of CO_2 emitted by new BEVs running on average EU electricity in 2030 is around 40% lower than compared to a petrol car running on e-fuels**. Over their lifetime, average European BEVs sold in 2030 would emit 51 gCO_2/km whereas the average e-petrol car is more than 80 gCO_2/km. If a combination of grid electricity and renewable electricity[19] is used to produce the e-fuel, the lifecycle emissions of a car with e-petrol would be 82 g/km while it would be 95 g/km for a combination of electricity from natural gas and renewables. Thanks to much lower overall electricity consumption, BEVs can perform better than e-petrol cars even when the carbon intensity of the electricity used to charge the car is higher than the one used to produce the fuel. By consuming five time more electricity for e-petrol even with a low lifecycle carbon intensity of the electricity used (between 66 gCO_2/kWh and 80 gCO_2/kWh) results in a situation whereby the total emissions accumulated over the lifetime of the vehicles can surpass those of a BEV running on more carbon intensive grid electricity (from 165 gCO_2/kWh in 2030 down to 56 gCO_2/kWh in 2040[20]).

[18] Transport & Environment (2020), *How clean are electric cars?* Link

[19] A combination of wind and solar is considered, based on the average expected mix between the two in 2030 (26% solar vs. 74% wind)

[20] ENTSO-E TYNDP 2020. For more see: Transport & Environment (2020), *How clean are electric cars?* Link



The electricity used to produce the e-fuel is based on the sustainability criteria from the REDII: 70% CO2 reduction compared to conventional fuels. In practice the electricity used to produce the e-fuel would be 70%-90% of additional renewable (depending if the renewable electricity is combined with gas or grid electricity).

Figure 5a: Lifecycle CO_2 emissions in 2030: BEV vs. e-petrol

Why are e-petrol lifecycle emissions higher when fossil gas power generation is combined with renewables rather than grid electricity?

Although both e-fuel production pathways here would meet the 70% RED II criteria, the difference between the two pathways comes from the fact that the WtW emissions from the grid electricity used in the methodology are calculated from two years prior to 2030, which means that actual lifecycle emissions of the electricity used to produce the e-fuel in 2030 are lower than the WtW emissions used to calculate the fuel emissions on paper. By using the 2028 figures and their higher carbon intensity due to a lower share of renewables compared to the situation in 2030, the e-petrol lifecycle emissions would be considered to be higher. The second reason comes from the fact that the share of renewables used to produce the e-fuels in combination with fossil gas power generation is higher (to compensate for higher emissions from fossil gas electricity versus average EU grid electricity). Hence the additional lifecycle emissions from renewables (when compared to zero emission renewables under the e-fuel sustainability production criteria) are more important because more of that renewables electricity is needed to produce the e-fuel when combined with fossil gas. On the other hand the difference between WtW and lifecycle emissions for fossil gas electricity production is much lower than for renewables, which means that the lifecycle emission scope brings a higher impact when the share of renewables is higher (for a given WtW sustainability criteria).

For comparison, in 2030, the petrol car running on conventional fuels would emit 192 gCO_2/km over its lifetime which is 2.0-2.3 times more than when running on e-fuels produced under the RED II sustainability criteria. In other words, powering a conventional car entirely on e-fuels only reduces life cycle CO_2 emissions by 51%-57%. In many cases the e-petrol would be blended with conventional petrol, leading to a lifecycle CO_2 emission performance which would sit somewhere between the 100% e-fuel values and the 100% conventional fuel value. For example, a petrol car running on a 50/50 e-fuel blend would reduce life cycle CO_2 emissions by 25%-29% (143-137 g/km).

The lifecycle CO_2 emissions of a BEV breaks even with an e-petrol car between 50,000 km and 80,000 km, which would be reached after around 3-5 years for the average driver. Figure 5b below shows the evolution of lifecycle emissions for e-petrol produced from both options presented above.

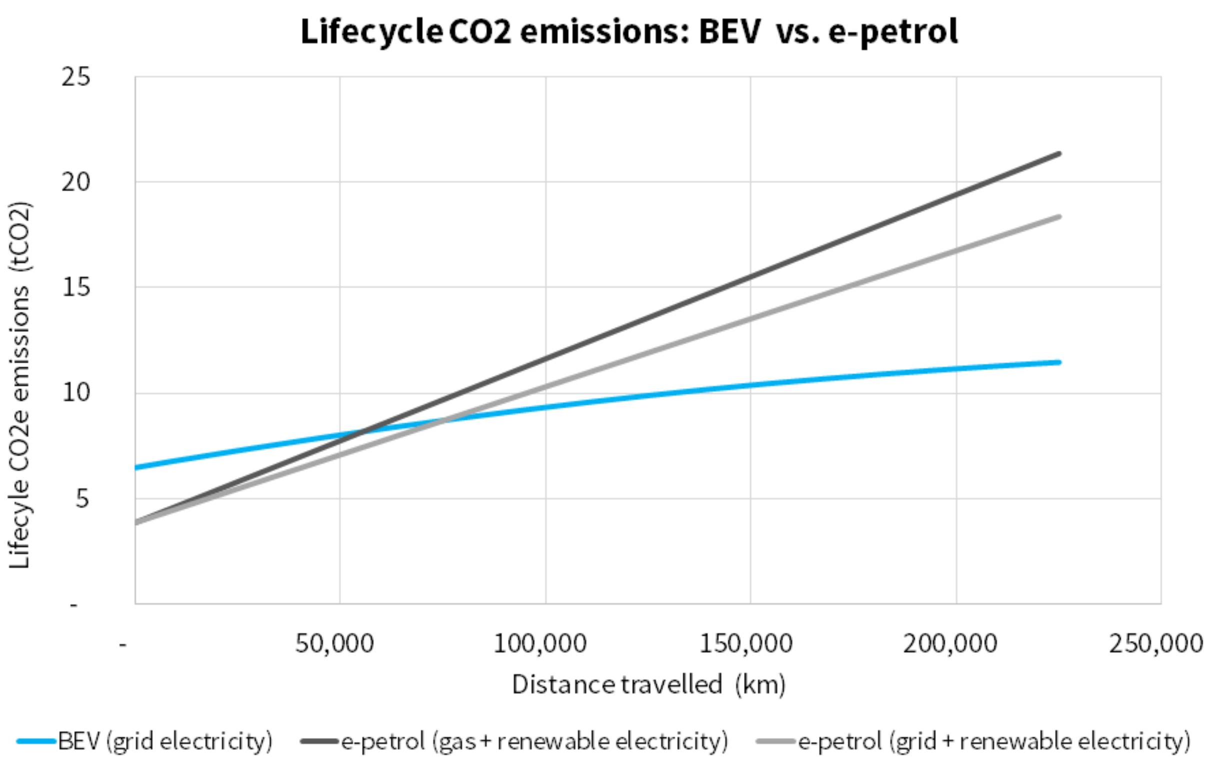


Figure 5b: Lifecycle CO_2 emissions in 2030: BEV vs. e-petrol (under RED II sustainability criteria)

For Germany - where there is a strong push for e-fuels to be part of the future cars mix - BEVs emit 28%-38% less CO_2 over their lifetime than e-petrol cars, while this drops to 60%-66% less for a BEV powered with renewables (e.g. electricity from Sweden).

The comparison presented above is nonetheless still favorable to e-petrol cars: synthetic fuels are assumed to be produced via an electricity mix which is almost fully decarbonised, whereas the electricity used to charge the BEV is based on the EU27 grid average, which still relies on close to a quarter of fossil fuel powered electricity in 2030 (mainly coal and gas) and is hence more than two times more carbon intensive. In the situation where the same electricity is used to produce the e-fuel and charge the vehicle[21], BEVs emit around half the emissions than a comparable e-petrol car (between 45% and 57%).

Even if 100% renewables electricity is used for efuels production[22], BEVs powered with the same mix are still much cleaner from the lifecycle emissions perspective, offering a 17% CO_2 reduction (33 g/km vs. 40 g/km), see Figure 6 below. This is explained by the fact that the lifecycle emissions of renewable electricity is not zero (primarily because of the production of the infrastructure), which means that by consuming a large amount of this electricity, the e-petrol powered cars can end up having a larger impact than the BEV even when we take into account the impact of the battery.

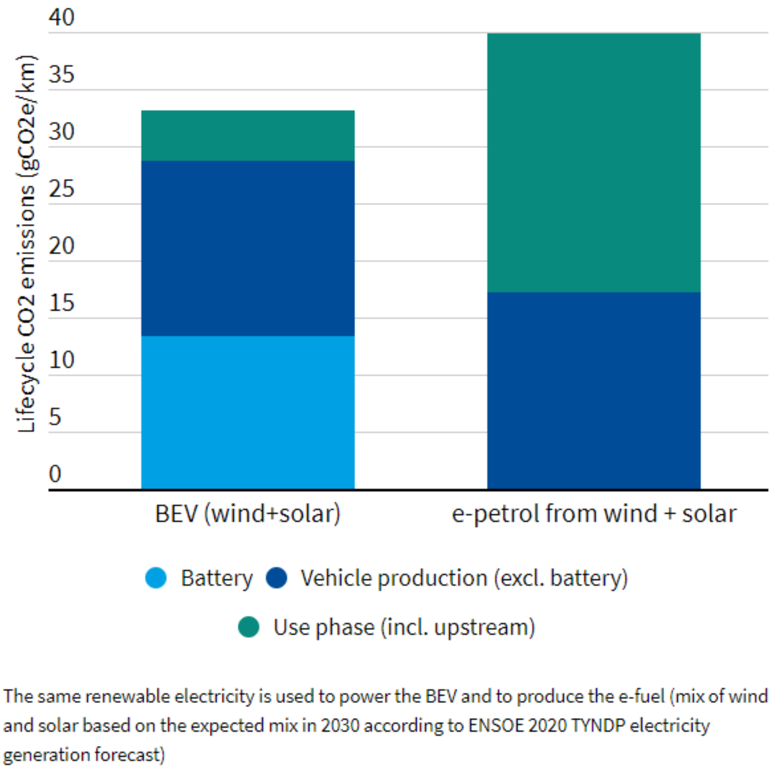


Figure 6a: Lifecycle CO_2 emissions in 2030: BEV vs. e-petrol (100% renewables)

Figure 6b below shows the evolution of lifecycle CO_2 emissions when both the e-petrol and the electricity used to charge the vehicle are from renewable electricity.

[21] Lifecycle carbon intensity of the electricity: 56 gCO_2/kWh
[22] Assuming only Wind + Solar PV, based on the 2030 split from ENTSO-E TYNDP 2020. Lifecycle carbon intensity of the electricity: 23 gCO_2/kWh

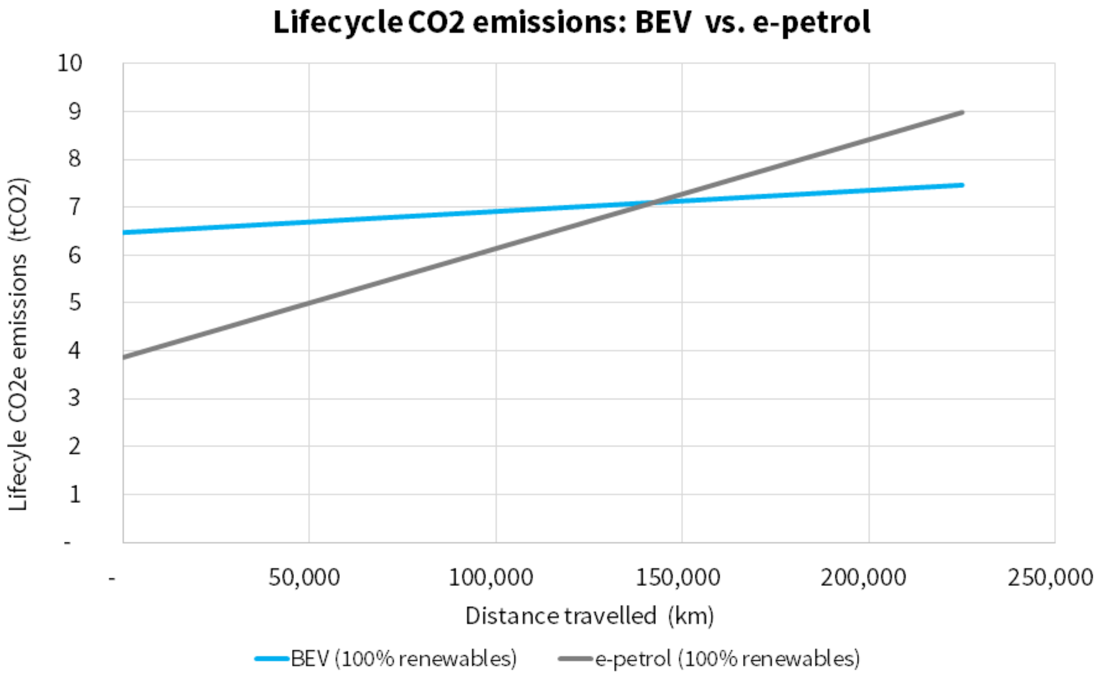


Figure 6b: Lifecycle CO_2 emissions in 2030: BEV vs. e-petrol (100% renewables)

Even in the hypothetical situation where e-fuels would be available today and the e-petrol car would be compared to a BEV running on today's electricity grid, the BEV would still be between 21% and 32% cleaner than the e-petrol car over the lifetime of the vehicle. This situation is however purely hypothetical given that such e-fuels do not exist today. Nonetheless, the finding highlights that -even before the 2030s- e-fuels cannot be a credible solution to reduce emissions. Over the years, as more renewables are incorporated into the electricity mix, the comparative advantage of BEVs over e-petrol cars only gets stronger.

In conclusion, under the current sustainability threshold for synthetic fuels (and assuming the most optimistic methodology for the calculator of the threshold), **conventional cars powered with e-fuels consistently emit more CO_2 than an equivalent BEV.** This result holds true even in the situation where the e-petrol is produced only with renewables and compared to a BEV running on renewables as well. The results are clear, using **e-fuels to power conventional cars cannot provide any considerable climate benefits in the context of widespread adoption of BEVs**.

4. Availability: e-fuels should not be diverted to cars where better alternatives exist

A recent study undertaken by Ricardo and commissioned T&E (December 2020)[23], has found that there is no scope to use renewable electricity inefficiently. Enabling the use of synthetic hydrocarbons in road

[23] Transport & Environment (2020), *Electrofuels? Yes, we can … if we're efficient.* Link

transport, where technical alternatives such as the direct use of electricity exist, comes with a huge energy penalty and risks derailing the entire decarbonisation effort.

The results of the study shows that relatively small variations in the use of hydrogen and efuels can add up can add up to large differences in terms of the renewable energy that will need to be produced. For example, if 100% of passenger cars were battery-electric, charging them would require 417 TWh in 2050 (just 15% compared to current total electricity demand). Enabling only 10% hydrogen plus 10% of synthetic hydrocarbons in cars would push up demand to 598 TWh or a 43% increase.

Inefficient use of e-fuels also results in a significantly higher area requirement. Delivering the energy needed for the synthetic fuel scenario would require an area equivalent to 5.1 times the area of Denmark if offshore wind would supply all of the additional electricity needed to decarbonise the transport sector (3.4 times in the base case). In other words, powering just a fraction of vehicles with e-fuels in 2050 would require new offshore wind-farms covering an area the size of Denmark.

With the whole economy relying on renewables, *'efficiency first'* matters given the large impact it can have on the renewable electricity requirement. Therefore, using less renewables is also most optimal as regards cost-effectiveness towards the energy system. Furthermore, there isn't expected to be any volumes of synthetic fuels on the market until after 2030[24], by which time plug-in cars will be by far the most efficient, cheap and convenient option.

The outlook is clear, **promoting even a limited use of synthetic fuels in road transport now will lock the EU's transport decarbonisation in a pathway that will require a much greater deployment of renewables than necessary**. This makes the transition harder to accomplish and could complicate the decarbonisation of the long-distance transport modes like aviation and shipping (which cannot use batteries to decarbonise).

5. Car CO_2 regulations: do not include fuel credits

On top of the strong economic, environmental, efficiency and availability arguments presented in this briefing, including e-fuel credits into the car CO_2 regulation cannot either be justified from the regulatory perspective. Indeed **carmakers cannot guarantee how cars are used or fueled over their lifetime**. They have no direct control over the choices of drivers and the suppliers' production processes. The vehicle regulation should only regulate what carmakers have control over, i.e. powertrains. Fuels should be regulated in appropriate EU legislation - as is the case already - such the EU Renewable Energy Directive and the EU Fuel Quality Directive. Thus keeping both sectors separate would maintain the effectiveness of each legislation. The effectiveness of the current design of the car CO_2 regulation has been proven in 2020 as the new targets propelled the EV market from 3% in 2019 to 10.5% in 2020[25].

[24] Even with very strong policy support and subsidies the potential volumes of CO_2-based synthetic fuels would be limited to approximately 0.15% of total EU road transport fuel demand in 2030.
[25] Transport & Environment (2020), *CO_2 targets propel European EV sales.* Link

The very **credibility of the car CO_2 regulation could be undermined** as car manufacturers could buy their way into compliance without making any improvements. Based on the amount of credits bought, a certain number of conventional cars on the road would be considered zero emission in their eyes of the regulation. This would likely be perceived very negatively by the average European which has been asking for zero emission cars[26].

Finally including synthetic fuels in the car CO_2 regulation also opens the door to the inclusion of other so called 'low or zero emission fuels' namely biofuels. These fuels are more affordable than efuels and would thus further reinforce the loophole and create a huge incentive to increase the use of biofuels although they are currently 80% worse than diesel[27].

T&E recommends[28]: **No CO_2 credits to carmakers for alternative or synthetic fuels should be included into the cars and vans CO_2 standards.**

Further information

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[26] Transport & Environment (2021), *Almost two in three European city dwellers want only emission-free cars aer 2030.* Link
[27] https://www.euractiv.com/section/agriculture-food/news/scientists-demand-end-to-crop-based-biofuels/
[28] Transport & Environment (2020), *Cars CO_2 review: Europe's chance to win the emobility race.* Link

6. Assumptions

General assumptions

Vehicles assumptions for a medium car (C-segment) in 2030

	BEV	Petrol	Source/comment
Fuel consumption (real-world) - 2030	0.17 kWh/ km	6 L/100km	Based on average values observed today for the BEVs. For the ICE, today's observed values. The value for petrol corresponds to today's hybrids (optimistic)
Fuel consumption (real-world) - 2025	0.173 kWh/km	6.5 L/100km	
Vehicle cost (2030)	22,200 €	27,200€	Cost trends are derived from (unpublished) study from BNEF (commissioned by T&E). The starting point is the (weighted) average vehicle cost of top selling vehicles in 2020[29]
Vehicle cost (2025)	28,000 €	26,100€	

Lifetime mileage: 225,000 km based on the European Commission study on LCA[30]. On average this is 15,000 km per year over 15 years[31]. No battery replacements are needed during the lifetime of the vehicle, in line with European Commission methodology and latest evidence[32].

Cost assumptions

Electricity prices are based on EU average 2020 (first semester) electricity costs from Eurostat and assumed constant up to 2030: 0.21€/kWh (0.13 €/kWh excluding taxes and levies)[33]

Conventional fuel prices are based on 2020 EU averages from the Oil Bulletin: petrol at 1.46 €/L (0.59 €/L without taxes) and diesel at 1.29 €/L (0.59 €/L without taxes). Taxes and levies account for 0.86 €/L for petrol and 0.70€/L for diesel.

Fuel price (including production, transport, distribution, taxes and levies)	Low		Central		High	
	2025	**2030**	**2025**	**2030**	**2025**	**2030**

[29] 2020/21 average: 34,500€ for BEVs and 25,400€ for petrol cars
[30] Ricardo Energy & Environment (2020), *Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA. Final Report for the European Commission, DG Climate Action.* Link
[31] In the LCA analysis and when calculating the average cost of e-fuel credits over the lifetime of a vehicle, the activity is assumed to decrease by 3% per year.
[32] Transport & Environment (2020), *How clean are electric cars?* Link
[33] Electricity prices for household consumers - bi-annual data (from 2007 onwards) [NRG_PC_204__custom_632753]. Band DC.

E-petrol	2.3	2.0	2.5	2.3	2.7	2.5
E-diesel	2.3	2.0	2.5	2.3	2.8	2.6

Other assumptions for the TCO calculation are listed below (for more details see T&E study on the cost of Uber[34]):

- Ownership period 5 years
- Maintenance cost: 300€ per year for the petrol cars and a reduction of 50% for the BEV.
- Residual value: 40% residual value after 5 years.
  - For a second hand ICE car bought in 2025, it is assumed that the residual value after 10 years (in 2035) is zero given the age of the vehicle and the strict limitation of petrol and diesel cars in cities (Euro 7 emission standard is not likely to be enforced by 2025, which makes these vehicles vulnerable to air quality restriction). In 2035 buyers would likely not choose a more expensive option which limits their ability to enter cities[35], thus driving down the residual value.
  - For second hand BEVs bought in 2025, the residual value after ten years is assumed to be 10% of the original price.
- No purchase subsidy or additional annual/circulation taxes were included in this assessment (conservative given increasing deployment of circulation taxes for ICEs in cities).
- Charging infrastructure:
  - Costs of home charger installation are factored in for the BEVs and estimated at €1,500 installation costs included. The cost of the charger is paid upfront and included in the 'others' cost category in the TCO infographic.
  - 5% of the energy is assumed to be delivered at fast public charging stations at 0.40 €/kWh.
- Financing:
  - Purchase option: the TCO model includes parameters linked to the vehicle acquisition mode (purchase, lease, or loan). The three scenarios impact the TCO only marginally; in the report all vehicles are assumed to be purchased, as this corresponds to the mid-price scenario. Cost effectiveness of BEVs vs. ICE can be improved by using leasing schemes, but deteriorates with loans.
  - Discount rate: 4%
  - Insurance costs: 3.5% of the vehicle upfront cost (annually). The insurance cost for 2nd hand cars was assumed the same as for 1st hand cars

Compliance pathway costs assumptions

- Fuel efficiency (real world): 7L/100km in 2020/2, 6.5 L/100km in 2025 and 6L/100km in 2020 (in line with a 1.5% annual improvement per year).
- BEV battery: 60 kWh
- Battery costs: 74€/kWh in 2025, 51 €/kWh in 2030 (based on BNEF battery price projection)

[34] https://www.transportenvironment.org/publications/why-uber-should-go-electric
[35] Indeed, by 2025, it is unlikely that new Euro 7 standards would be enforced which means that those vehicles could be subject to high restrictions

Social cost assumptions

Assumptions for the share of revenue in e-fuel and battery production which flow back to (or stay within) Europe (authors assumptions).

- Electricity cost of hydrogen electrolysis: 10% (allocated to RES and utility industry)
- Cost of conversion of hydrogen electrolysis: 30% (allocated to hydrogen industry)
- Storage cost for hydrogen: 30% (allocated to hydrogen industry)
- CO_2 cost: 30% (allocated to fuels industry)
- Investment cost: 30% (allocated to fuels industry)
- Operating cost: 30% (allocated to fuels industry)
- Battery: 65% (allocated to the battery production industry)

Lifecycle CO_2 emission analysis

In the LCA analysis of e-fuels, T&E assumes that the 70% sustainability criteria under REDII for the production of synthetic fuels is based on the WTW emissions from the different energy sources. If the final methodology adopted by the European Commission (due by the end of 2021), decides to use the wider lifecycle scope and accounts for infrastructure emissions (i.e. renewables are not counted as zero), then lifecycle CO_2 emissions from conventional cars powered with e-fuels would be slightly lower (between 12% and 25% lower depending if fossil gas or grid electricity is used in combination of renewables). This is explained by the fact that a higher share of renewable electricity would be needed to reach the 70% sustainability criteria and balance off the higher emissions from electricity from natural gas or grid electricity given they are not counted as zero emissions. This option is not presented in this paper.

The well to wheel emissions for petrol and diesel fuels used as a reference for the European Commission is of 94 gCO_2/MJ. Therefore, the maximum lifecycle CO_2 emission from e-petrol and e-diesel fuels under the REDII 70% criteria would be 28 gCO_2/MJ.

T&E modelled different scenarios for the electricity sources that can be used in e-fuel production and their respective shares in the electricity used. The WTW and lifecycle carbon intensity of each electricity supply technology is based on IPCC's Fifth Assessment Report[36].

All other assumptions used in the LCA modelling are presented in T&E's lifecycle CO_2 analysis report 'How clean are electric cars?'[37], with the exception of the following updates:

- The petrol car fuel consumption was set at 6 L/100km in 2030 (see above, General assumptions).
- The BEV energy efficiency was set at 17 kWh/km in 2030 (see above, General assumptions).
- The lifecycle emissions of the electricity mix in 2020 was updated based on recent evidence from Ember[38]. Direct CO_2 emissions from Ember in 2020 are 226 gCO_2/kWh (EU27) while T&E

[36] Intergovernmental Panel on Climate Change, IPCC (2014), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the IPCC - Annex III. Link. Median values assumed

[37] Transport & Environment (2020), *How clean are electric cars?* Link

[38] Ember (2021), *EU Power Sector in 2020.* Link

calculates life cycle CO_2 emissions at 285 gCO_2/kWh (without transmission and distribution losses).

- Battery production in 2030: The upstream emissions from battery production (ie steps before the cell production and pack assembly) will decrease in the next decade thanks to the overall decarbonisation of the world economy. T&E assumes that the carbon intensity of the upstream stage of battery production is reduced by a quarter between 2020 and 2030. This is approximately half of the world or European improvement of the carbon intensity of electricity[39]). This effectively brings down the carbon footprint of batteries produced in the EU to 50 $kgCO_2$/kWh in 2030 (upstream accounting for 41 $kgCO_2$/kWh out of 50$kgCO_2$/kWh).

[39] IEA (2020), *Carbon intensity of electricity generation in selected regions in the Sustainable Development Scenario, 2000-2040.* Link