ARTFuels

Joint Heavy-Duty Vehicles & Passenger Cars Position Paper

SUMMARY AND KEY MESSAGES

- The transport sector is responsible for some 25% of the overall fossil GHG emissions. Out of that, 70% is coming from road transport, which presently is almost entirely dependent on fossil fuels (>95%)[1].
- Transport is the largest single emitter within the non-ETS sectors. All EU countries have to commit to binding reduction targets from the non-ETS (30% on average) until 2030. For some countries, thought, this requirement is a 40% reduction[2]. In contrast to other sectors, emissions from transport are still increasing.
- Although electrification of road transport will increase and there will be significant efficiency improvements, driven notably by tightening vehicle CO_2 emission regulations, **the GHG reduction requirements for 2030 (and beyond) cannot be met without renewable fuels.**
- **Currently, renewable and low carbon fuels provide one of the most cost-effective means to reduce GHG emissions from transport.**
- **Renewable fuels can support all modes of road transport, thus, contributing to the decarbonisation of the current circulating fleet.**
- The role of internal combustion engines will remain significant for road vehicles well beyond 2030, particularly for heavy duty vehicles[3]. **All renewable fuels that can replace fossil fuels in transport and, thus, reduce the GHG footprint of this sector, should be considered and supported.**
- **Sustainably produced renewable fuels will have an important role to play for many years to come,** e.g., the International Energy Agency calls for a tenfold increase in biofuel volumes from 2015 to 2060[4].
- In light of the points above, adequate policy and economic support should be put in place to make sure that the potential of renewable fuels is fully harnessed.
- **A holistic view is particularly important: energy, materials and the vehicle itself form a complex system**. Assessing the whole system from just one point of view such as the sole emissions from the tailpipe (tank-to-wheels; TTW) leads to incorrect conclusions. A well-to-wheels (WtW) or complete vehicle lifecycle approach should be applied for GHG emissions and energy efficiency.
- In essence, the present vehicle CO_2 regulations, focusing on tailpipe CO_2 only, largely overlook the overall GHG emission reduction potential of renewable fuels and consequently do not promote these. The legislation uses CO_2 as 'metric' rather than energy use and does, therefore, not promote efficiency improvements for all types of fuels. Furthermore, it does not differentiate between biogenic and fossil CO_2 and, therefore, fails to distinguish the renewable carbon containing fuels from fossil fuels.
- **To make it attractive for vehicle manufacturers to produce and market alternatively fuelled vehicles, the legislation should provide dedicated measures and/or incentives.** Various policies, Directives and Regulations (e.g., climate and energy targets, vehicle CO_2 regulations, promotion of renewable energy and clean vehicles, deployment of alternative fuels infrastructure) should be in congruence.

[1] https://ec.europa.eu/clima/policies/transport_en
[2] https://ec.europa.eu/clima/policies/effort/regulation_en
[3] https://journals.sagepub.com/doi/full/10.1177/1468087419877990
[4] https://webstore.iea.org/technology-roadmap-delivering-sustainable-bioenergy

SUMMARY AND KEY MESSAGES

- **Provided that they comply with strict sustainability criteria, fuels containing renewable or recycled carbon should not be disincentivized compared to direct use of electricity and hydrogen.** The overall GHG performance should be a key indicator. These liquid and gaseous fuels will be needed also in the future as all modes of transport are not suitable for electrification.

Annex

Renewable fuels are vital for transport decarbonisation

Renewable fuels provide a bypass lane to transport decarbonisation. Liquid renewable fuels can power all modes of transport, including marine and aviation. Biomethane, either in gaseous or liquefied form, can cater for the needs of all forms of road transport, including heavy-duty long-haul operations. Renewable fuels help the EU to reduce dependency on imported crude oil and fossil products, to improve domestic security of supply and to generate local business opportunities.

Within the group of fossil fuels, LPG and natural gas can reduce tailpipe carbon dioxide (CO_2) emissions from transport to some extent compared to petrol and diesel (stems from the more favourable carbon to hydrogen ratio of these fuels).

Within the EU, transport accounts for some 25% of total greenhouse gas (GHG) emissions[5] and 30.8% of the EU final energy consumption, being the second largest emitter after power generation. Within transport, more than 70% of the emissions stem from road transport. When moving towards carbon neutrality, transport is one of the key sectors to address, especially since GHG emissions from transport have increased compared to 1990 levels, whereas other sectors show declining emissions (Figure 1).

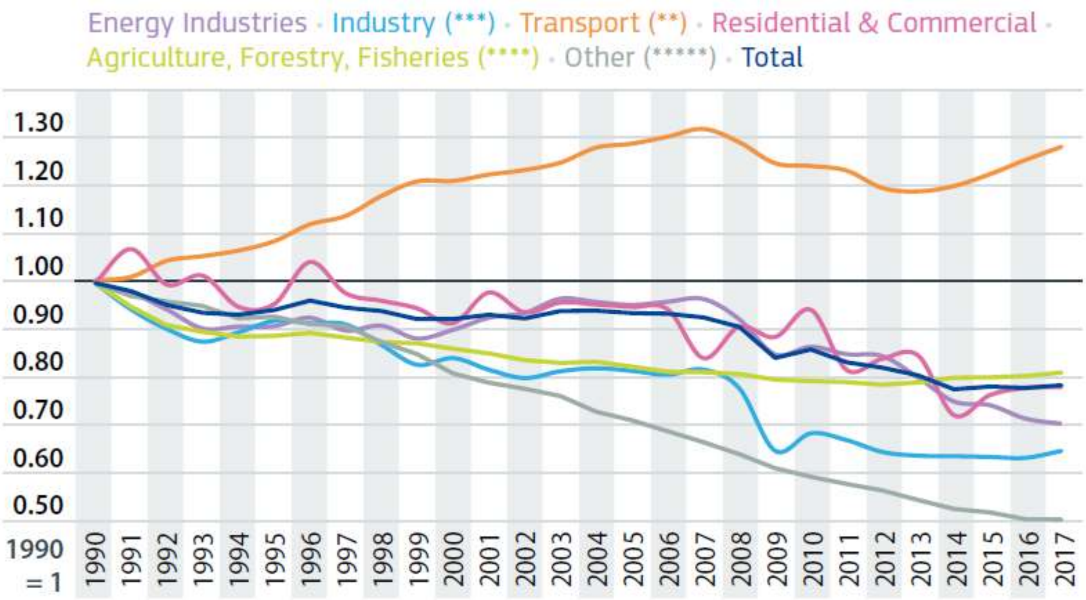

Figure 1. GHG emission trends in Europe[1].

The EU climate and energy targets for 2030 have already been set[6]. Overall GHG emissions have to be reduced by at least 40% compared to the year 1990. Non-ETS (Emission Trading Sector) sectors, including transport, will need to cut emissions on an average by 30% (compared to 2005). This has been translated

[5] https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2019_en
[6] https://ec.europa.eu/clima/policies/strategies/2030_en

into individual binding targets for Member States, varying from 0 to 40%, depending on, e.g., GDP. For instance, France, Germany, Denmark, Finland, Sweden and Luxembourg all have high targets, being obliged to reduce their non-ETS emissions by 37-40%. This puts enormous pressure on reducing emissions from transport. The updated Directive on the promotion of the use of energy from renewable sources (RED II[7]) in principle calls for at least 14% renewable energy in transport by 2030. The actual figure can be lower for a number of reasons (e.g., share of crop-based biofuels lower than 7% and multipliers in some cases). For many countries, the share of renewables called for by RED II will simply not be enough to meet the requirements for GHG reductions in the non-ETS sector.

The key measures for transport decarbonisation are 1) improving energy efficiency at the vehicle level as well as throughout the whole transport system, 2) introducing of renewable and low carbon fuels and 3) electrification. None of these measures conflicts with each other and should in fact complement each other.

The combined impact of the various measures depends on the timeline and whether new vehicles and new infrastructure have to be put in place. Average age of vehicles in Europe is 11.1 years for passenger cars, 11 years for light commercial vehicles and 12 years for heavy commercial vehicles[8].

The success of electrification will depend on the renewal of the fleet and on setting up new recharging infrastructure. According to statistics from ACEA in the passenger car segment, electrically chargeable vehicles (ECVs) made up 3.0% of total new car sales across the EU in 2019. Electric buses had a share of 4% while for medium- and heavy-duty trucks the share of ECVs was only 0.2%[9]. Despite the projected rapid increase in ECV numbers, mainly driven by vehicle CO_2 legislation, the expected impact of electric vehicles by 2030 is still rather limited because of the slow fleet renewal.

Thus, renewable fuels, compatible with the legacy fleet as well as with new internal combustion engine (ICE) vehicles entering the market from this point on, will play a major role in transport decarbonisation in 2030 and well beyond. Policy makers should be made aware that the goals for deep decarbonisation of transport simply cannot be achieved without renewable fuels; renewable fuels and electrification should be promoted side by side (Figure 2).

7 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN
8 https://www.acea.be/statistics/article/average-age-of-the-eu-motor-vehicle-fleet-by-vehicle-type
9 https://www.acea.be/statistics/tag/category/electric-and-alternative-vehicle-registrations

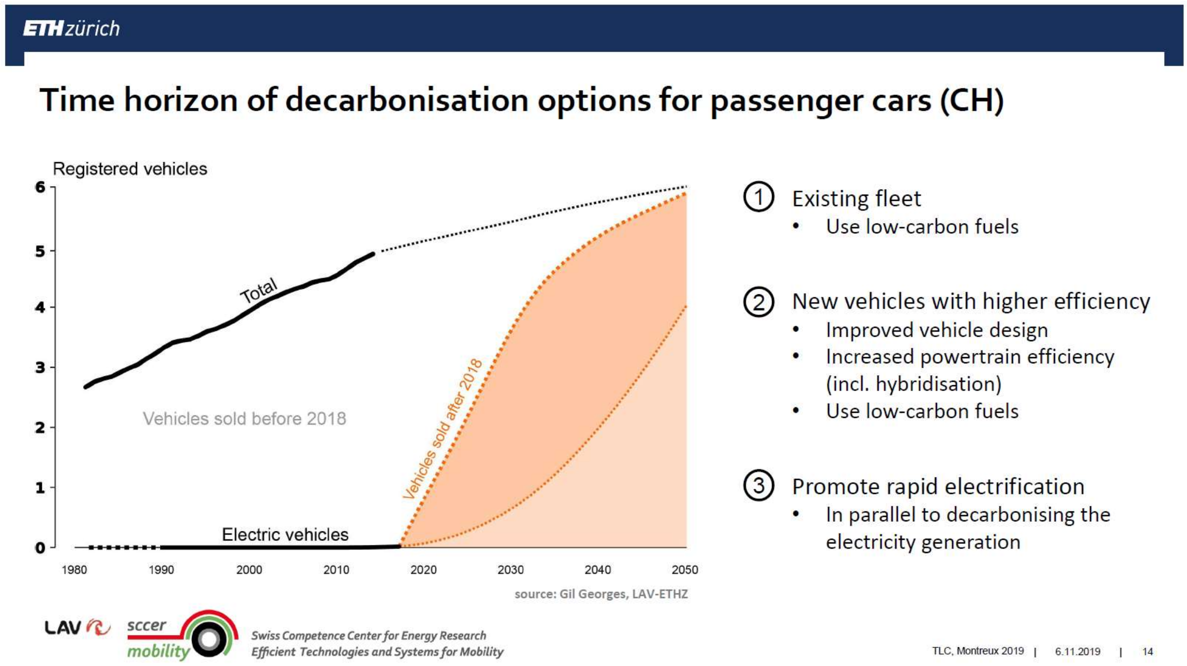

Figure 2. Time horizon in decarbonizing the passenger car fleet[10]. Please note that decarbonisation by electrification requires renewable/low carbon electricity (as in the case of Switzerland).

Vehicle and fuel compatibility are important

There are different levels of compatibility, starting from materials compatibility (affecting, e.g., safety, durability and operability) to the full technical and legal compliance of the combination of the vehicle and the fuel to be used. In markets with stringent vehicle and emission regulations, such as the EU, vehicles and fuels have to be "on par"; meaning that the vehicle should be approved and certified for the fuel it is operating on. Changing the fuel might have effects on the engine itself, the exhaust after-treatment system and even the lubricant. One can, thus, state that the fuel is not a parameter that can be freely varied, it has to be a part of a balanced and legally secured system.

Fuel quality and fuel composition are regulated on various levels, both internationally and nationally. In parallel to fuel quality, exhaust emissions are also regulated. The three main levels of documents related to fuel quality and fuel composition are:

- legally binding rules;
- standards;
- guidance.

The highest level, i.e. the legal framework, is defined by laws, Directives and Regulations. For the European Union, the Directive on fuel quality (FQD[11]), concerning petrol and diesel, defines the fuel parameters most critical for exhaust emissions. The FQD sets limits for oxygenated biocomponents, currently, e.g., maximum 10% (v/v) ethanol in petrol (corresponding to an oxygen content of 3.7% m/m) and maximum 7% (v/v) FAME (Fatty Acid Methyl Ester) in diesel (B7)[12]. The so-called blending walls are in

[10] K. Boulouchos, ETH Zurich, 2019
[11] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0030&from=EN
[12] The FQD states:, Member States may permit the placing on the market of diesel with a fatty acid methyl ester (FAME) content greater than 7%

place to safeguard the operation of conventional unmodified vehicles. Components, which are not limited in concentration, e.g., HVO, are often called drop-in components.

The second level is standards (in the case of Europe CEN standards). Standards are, in principle, voluntary agreements and have as such no legal status. However, in some EU Member States full CEN-standards are referenced in legal documents and in those cases, the standard becomes equal to a legally binding document. Fuel standards include parameters that are important for the technical functionality of the fuels and are in that sense more comprehensive than the legally binding fuel requirements. The FQD alone lists 6 parameters for diesel fuel, whereas the European standard for diesel fuel, EN 590[13], lists 16 parameters to be controlled. The additional parameters relate to functionality and vehicle durability, e.g., lubricity, corrosion, ash, sediments, oxidation stability and cold operability.

Figure 3 presents an overview of the European fuel standards currently in place. EN 228 is commercial grade petrol and EN 590 commercial grade diesel fuel. These standards fall back on the FQD regarding blending limitations for oxygenates.

Not all of the EN fuel standards are necessarily for use as motor fuels or as such (e.g., EN 16900 specifies fast pyrolysis bio-oils for boiler use at industrial scale, EN 15376 ethanol used as a blending component).

Important standards regarding alternative fuels are:

- B10: EN 16734;
- B20/B30 for captive fleets: EN 16709;
- Biodiesel FAME B100: EN 14214;
- Paraffinic diesel: EN 15940;
- E85 : EN 15293;
- CNG/LNG (methane): EN 16723-2;
- LPG: EN 589.

Emission certification fuels exist for conventional petrol (E10) and diesel fuel (B7), E85, methane fuels and LPG, to allow engines to be certified with these fuels. In addition, the Euro VI emission regulation for heavy-duty vehicles stipulates that a diesel engine must be certified for the fuel that it will be using. Thus, some heavy-duty manufacturers have certified engines for EN 590 as well as for B100 (100% conventional FAME biodiesel) and for HVO100 (100% paraffinic renewable diesel, hydrotreated vegetable oil). For HVO100 no real modification to engine calibration or fuel system hardware is needed, while for B100 the necessary adaptions can be somewhat more significant, including changes in maintenance schedules.

A list of commercial vehicles approved for B20/30/100 can be found at: https://www.agqm-biodiesel.de/application/files/4715/2992/5789/WEB_AGQM_0216_FREIGABEN.pdf

[13] **EN 590:2013+A1:2017** (WI=00019524) Automotive fuels - Diesel - Requirements and test methods

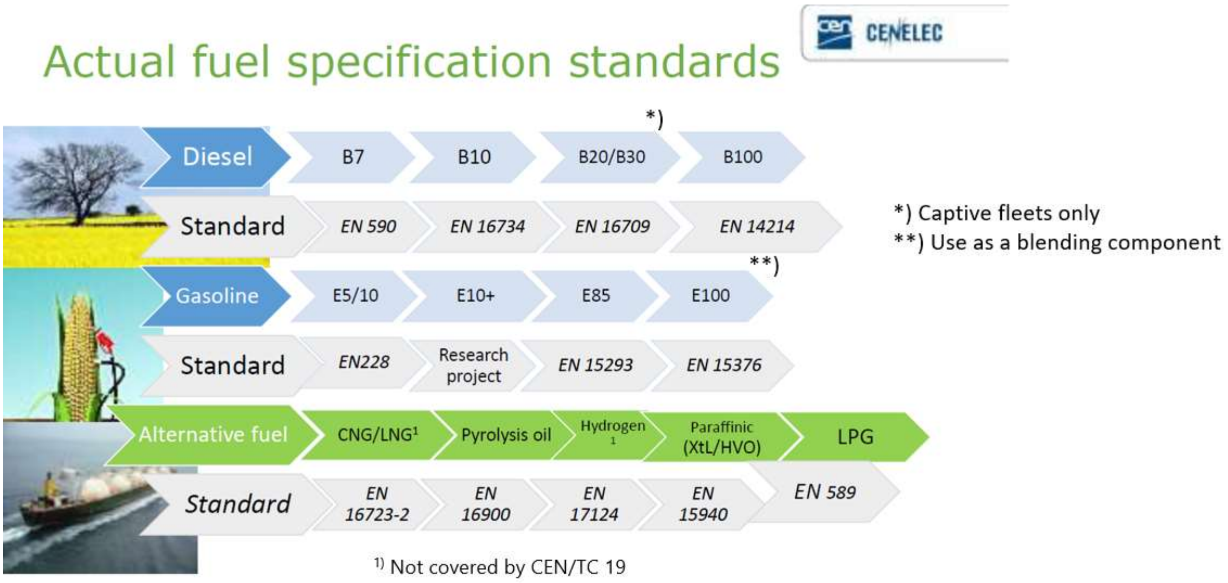

Figure 3. Current European fuel standards[14].

The third level is guidance documents and industry recommendations. One example of guidance documents is the "good housekeeping guide for diesel fuels" (CEN/TR 1536715). An example of an important industry recommendation is the Worldwide Fuel Charter (WWFC)16 of the car and engine manufacturers. The WWFC presents the joint fuel quality requirements of the automotive industry and makes a strong link between vehicle emissions regulations, including CO2, and the fuel quality needed to be able to fulfil those legal requirements.

Multiple approaches to the use of renewable fuels

There are in principle three different ways to introduce renewable fuels for road vehicles:

- Low level blending of traditional biocomponents, e.g., ethanol, ETBE, biodiesel (FAME) within existing market fuel standards (EN 228, EN 590);
  - *Simple solution, but limited impact of less than 10% energy replacement due to current limits of the regulations*
- Drop-in type components[17] suitable for high level blending in conventional petrol and diesel fuel;
  - *Drop-in fuel means a fuel that is fully fungible with conventional hydrocarbon fuels and compatible with existing vehicles and fuel infrastructure in any portion.*
  - *Simple solution, impact can be high, up to 100% replacement, paraffinic renewable diesel (Hydrotreated Vegetable Oil HVO, Biomass-to-Liquids BTL) is a kind of silver bullet for diesel.*
  - *Availability of large amount of sustainable feedstock (REDII compliant) is, however, an issue.*
  - *At present, there are no good biocomponent options available for high level blending in petrol. Commercial availability of bio-petrol hydrocarbons (bio-naphtha) compounds is very limited and related to HVO production as a whole. The low octane rating of bio-naphtha needs to be considered in light of the future development of high-octane petrol.*

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[14] ps://www.nen.nl/Evenementen/Presentaties/20190625-Presentaties-Future-fuels.htm?utm_medium=email
[15] https://infostore.saiglobal.com/en-us/Standards/CEN-TR-15367-1-2014-334308_SAIG_CEN_CEN_767928/
[16] https://www.acea.be/uploads/publications/WWFC_19_gasoline_diesel.pdf
[17] Definition by IEA Bioenergy: "Drop-in" biofuels are defined as liquid hydrocarbons that are oxygen-free and functionally equivalent to petroleum transportation fuel blendstocks, https://www.ieabioenergy.com/publications/the-potential-and-challenges-of-drop-in-biofuels/

- Dedicated fuels for dedicated vehicles;
  - *Gaseous fuels (methane, LPG, DME), high concentration alcohol fuels (E85, ED95, M85, M100)*
    - *In the case of methane biomethane can be considered a drop-in substitute for fossil natural gas*
    - *In the case of LPG, bioLPG is a chemically identical drop-in fuel that can be blended at any rate and used with existing infrastructure*
  - *"Chicken and egg" dilemma, what comes first, fuel infrastructure or vehicles?*

All of these alternatives have their pros and cons, and most probably, all will be needed to decarbonise road transport. From an end-use perspective, the origin or feedstock of the fuel is of less significance. If properly processed and refined, the feedstock origin and properties will not affect the properties of the end product to any extent. The emissions of biogenic CO_2 from combustion of biofuels (end-use) is set to be zero according to the EU ETS[18] and RED II Directives. The sustainability criteria and calculation rules for renewable fuels of non-biological origin (electrofuels) and recycled carbon fuels are still to be defined in detail in upcoming delegated acts.

Currently the renewable fuels offered in the largest volumes are ethanol and FAME type biodiesel. Drop-in type renewable hydrocarbons are more limited in supply, especially renewable components for petrol. This might change over time when new technologies, such as producing fuels from renewable electricity and captured carbon dioxide (electrofuels, or Power-To-X, PtX), become commercial.

Dedicated engine technologies are available for gaseous fuels as well as for high blends of alcohol fuels. Dedicated concepts could deliver advantages for both efficiency and pollutant emissions. However, the offering of alternative fuel vehicles is somewhat limited, and the same could be said for some of the fuel options. In Europe, only Ford[19] offers flexible-fuel passenger cars (E85/petrol). There are two manufacturers (the FCA Group[20] and the VAG Group[21]) producing methane fuelled passenger cars. Retrofitting vehicles is an option for both E85 (as demonstrated in France) and gaseous fuels (LPG as well as natural gas). However, original equipment manufacturer (OEM) vehicles would be the preferred option for a number of reasons.

As for heavy-duty vehicles, there has lately been an increase in the offering of heavy-duty methane trucks. There is also an ample offering of methane fuelled buses and coaches. A listing of available methane vehicles can be found on NGVA Europe's website[22]. Only one manufacturer (Scania[23]) offers dedicated heavy-duty ethanol engines.

As long as the FQD and fuel standards limit the use of ethanol and FAME in conventional fuels and the offering of dedicated vehicles is limited, fungible hydrocarbon type renewable fuels hold the promise of the greatest future impact. However, for that to happen, sustainable feedstocks and a new magnitude of investments in production facilities have to be secured.

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18 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0087&from=EN
19 https://bioenergyinternational.com/storage-logistics/ford-reintroduces-e85-powered-cars-to-sweden
20 https://www.fiat.it/auto-a-metano
21 https://www.volkswagen-newsroom.com/en/natural-gas-engines-tgi-3652
22 https://www.ngva.eu/medias/vehicle-catalogue-2019/
23 https://www.scania.com/group/en/home/newsroom/news/2018/first-scania-bioethanol-truck-hits-the-road.html

What can internal combustion engine (ICE) vehicles and Renewable Fuels deliver?

The emission performance of ICEs is a combination of the engine itself with its exhaust control system and the fuel. Engine and exhaust control technology are decisive to control (regulated) pollutants emissions, whereas the fuel itself is decisive for overall GHG emissions. This means that one tackles local emissions with advanced exhaust after-treatment technology, and global GHG emissions with vehicle efficiency improvements and renewable energy carriers, including renewable fuels as well as renewable electricity.

Diesel vehicles took a hit from the 2015 emission scandal, which was about passenger car nitrogen oxide (NO_x) non-compliance, i.e. local pollution[24]. The situation was not caused by lack of technology, but rather by shortcomings in emission legislation. As of 2017, requirements concerning real driving emissions (RDE) have been phased in, and emissions of new diesel cars are now well under control. Already starting as of 2013, the Euro VI emission regulation for heavy-duty vehicles encompassed a requirement of in-service conformity (ISC), equivalent to the passenger car RDE requirement.

Today one can make the statement that, in a historical perspective, all new vehicles are clean regarding local emissions. Figure 4 shows how NOx and particulate emission (PM) of city buses have been reduced over the years. At the Euro VI level, the differences between fuels are practically non-existent, as the emission control technologies are so efficient. However, in older generations of vehicles, chemically simple alternative fuels, such as methane, can provide reduced pollutant emissions, especially reduced PM emissions.

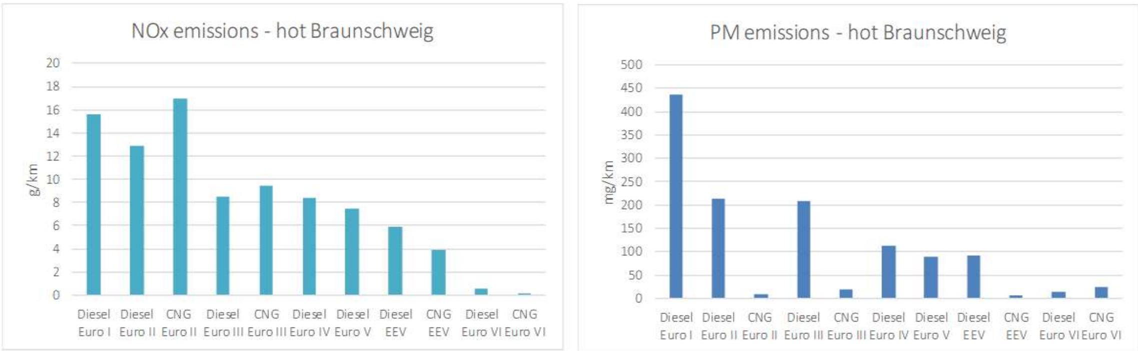

Figure 4. Trend of NO_x and PM emission from city buses (Euro I-VI)[25].

GHG emissions from alternative energy carriers should be assessed over the whole energy chain, i.e. well-to-wheel (WtW) or, in other words, from the production of the fuels to its use in the engine. Annex V of the RED II Directive presents default GHG savings for various biofuels and bioliquids. Compared to the fossil fuel comparator, biofuels reach WtW GHG savings in the range of 70 to 80 %. Default saving values for advanced future biofuels go as high as 89 %[7].

RED II sets the fossil fuel comparator at 94.1 g CO_{2eq}/MJ. A compact diesel passenger car typically consumes some 5 litres/100 km or 1,8 MJ/km. This results in a WtW CO_2 emission of 169 g CO_2/km when running on neat fossil diesel. With advanced biofuels such as waste wood Fischer-Tropsch diesel, this could be reduced down to about 20 g CO_2/km. The same kind of calculation for a compact battery electric

[24] https://www.theguardian.com/business/ng-interactive/2015/sep/23/volkswagen-emissions-scandal-explained-diesel-cars
[25] Nylund, N.-O. et al. (2020, April 27-30). On route to clean bus services. Transport Research Arena 2020, Helsinki, Finland. (Conference cancelled)

vehicle at 0.15 kWh/km running on average European electricity at 296 g CO2/kWh (value for 2016[26]) and taking into account transmission losses (estimated at 5 %) produces a figure of some 50 g CO_2/km. The calculation in presented in Table 1.

Table 1. Example of calculating well-to-wheel CO_2 emissions for compact passenger cars. Data from RED II and European Environment Agency.

	Fossil diesel	EV EU avg. electricity
Fuel consumption (l/100 km)	5.0	
Energy consumption (MJ/km)	1.8	0,54
Energy consumption (kWh/km)		0,15
Transmission losses (%)		5
Energy feed		0,16
CO_2 intensity (g CO_2/MJ)	94	
CO_2 intensity (g CO_2/kWh)		296
CO_2 emission (g/km)	169	47
Renewable diesel		
GHG emissions saving - default value waste wood FT diesel (%)	85	
WtW CO_2 emission renewable diesel (g/km)	25	

Electric vehicles currently are more energy and GHG intensive to produce than ICE vehicles. Expanding the assessment to a full life cycle assessment, i.e. taking into account building and scrapping the vehicle, the outcome is that for overall lifetime GHG emissions, an ICE vehicle operated on the best of renewable fuels is on par with a battery electric vehicle running on renewable electricity[27].

In summary, the newest ICE vehicles combined with renewable fuels can provide an affordable combination of low pollutant emissions and low overall GHG emissions.

A level playing ground needed

It is important that all renewable fuels - regardless if they are categorised as conventional (also named crop-based or 1st generation) or advanced (also called 2nd generation) - are recognised and supported in accordance with their potential to reduce GHG emissions and reliance on fossil fuels. This potential should be demonstrated for each fuel production pathway and judged using a WtW perspective. The JEC (JRC-Eucar-Concawe) WtW study 2014[28] is widely used for this purpose since many years, but there are also other studies that are well recognized. The JEC study is being updated (to version 5) and will now for the first time also include heavy-duty vehicles.

Unfortunately, the present CO_2 legislation for vehicles (light-duty as well as heavy-duty) is based solely on tail pipe CO_2 emissions (tank-to-wheel, TtW). This means that, in this legislation, carbon-containing biofuels (HVO, B100, ethanol, bio-methanol etc) will show no or very limited CO_2 benefits when comparing to their fossil counterparts, because of the lack of distinction between biogenic and fossil carbon.

[26] https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-5#tab-googlechartid_chart_11_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_ugeo%22%3A%5B%22European%20Union%20(current%20composition)%22%5D%7D%7D

[27] http://www.etipbioenergy.eu/images/SPM8_Presentations/t_4_180412%20Pengg%20Audi_Decarbonisation%20transport%20sector.pdf

[28] https://ec.europa.eu/jrc/en/jec

Furthermore, the vehicle legislation disadvantages carbon containing fuels (including renewable ones) over energy carriers not containing carbon like electricity or hydrogen. Regardless whether the electricity is produced from fossil energy (e.g., coal, natural gas) or from renewable resources, the benefits of being "zero CO_2 emissions" at the vehicle stage will always be there in the present legislation.

If the cost for emitting fossil CO_2 (€/tonne CO_2) would be equal in all sectors, this would be less of an issue. In that case, the CO_2 penalty would be equalized and there would be a level playing field between all sectors and end uses. The price for a tonne of CO_2 in the European ETS system is currently (May 2020) some 25 €/tonne[29]. This gives, e.g., coal-based electricity an unfair advantage compared to transport biofuels. The "per tonne" penalty for not meeting the CO_2 emissions requirements at the vehicle level, even when using advanced biofuels, is much higher than the ETS CO_2 price, typically by a factor of 5 to 10.

The OEMs therefore currently have no incentive to produce vehicles especially adapted for high concentration renewable fuels. This is especially true regarding mono-fuel heavy-duty vehicles (ED95, methanol, DME).

Although the aim of the heavy-duty legislation is to improve vehicle efficiency, tailpipe CO_2 is used as the sole 'efficiency metric' in the legislation. The VECTO (Vehicle Energy Consumption Tool[30]) simulation tool does actually report also in 'energy terms' (kWh/tonne km) but only CO_2 (gram CO_2/ tonne km) is used for legislation purposes. The vehicle legislation could be modified to become a true vehicle efficiency enhancing legislation and consequently based on 'energy used per km' (passenger cars) or 'per tonne km' (heavy duty).

To achieve a level playing field between biofuels, electricity and hydrogen, ideally a WtW approach should be used for overall CO_2 emissions and energy use, and ultimately, even the use of materials should be accounted for. The Commission is evaluating the feasibility of LCA assessment for vehicles[31], and ACEA mentions WtW as a possible addition to future regulations[32].

There is certainly a need for a solid legislative link established between climate targets, fuel legislation (FQD, RED, alternative fuel infrastructure DAFI[33]) and vehicle CO_2 legislation.

Current use of renewable fuels and future potential

Within the EU, the use of biofuels in transport has mainly been driven by Directives on the promotion of renewable energy (2003/30/EC34, 2009/28/EC35 (RED), (EU) 2018/20014 (RED II).

Directive 2003/30/EC set an indicative target of 5.75% biofuels (on an energy basis) on an average in petrol and diesel fuels by 2010. Directive 2009/28/EC calls for 10% renewable energy in transport in 2020, and Directive (EU) 2018/2001 for 14% renewable energy in transport in 2030 (mandatory targets). RED II contains a sub-target of 3.5% for advanced biofuels.

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29 https://markets.businessinsider.com/commodities/co2-european-emission-allowances
30 https://ec.europa.eu/clima/policies/transport/vehicles/vecto_en
31 https://www.upei.org/images/Vehicle_LCA_Project_FinalMeeting_All_FinalDistributed.pdf
32 https://www.acea.be/publications/article/paving-the-way-to-carbon-neutral-transport-10-point-plan-to-help-imple
33 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094&from=FI
34 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0030&from=EN
35 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN

Currently, the only commercially viable renewable alternatives for transport are biofuels and renewable electricity. Renewable fuels of non-biological origin (e-fuels) are still in the early piloting phase. Electrification, on the other hand, is dependent of fleet renewal.

As biofuels are, in most cases, more expensive than conventional fossil fuels, Member States have facilitated deployment of biofuels first with tax incentives and then with mandates. EU State Aid rules do not allow combination of these two measures.

Figure 5 shows development of biofuel shares within EU. Shares grew steadily between 2005 and 2012 but stagnated until 2017. The stagnation can partly be explained by uncertainty in policy (e.g., discussions on sustainability and the ILUC Directive[36], update of the Renewable Energy Directive, rules changing every 3-5 years). In 2018, consumption of biofuels picked up again.

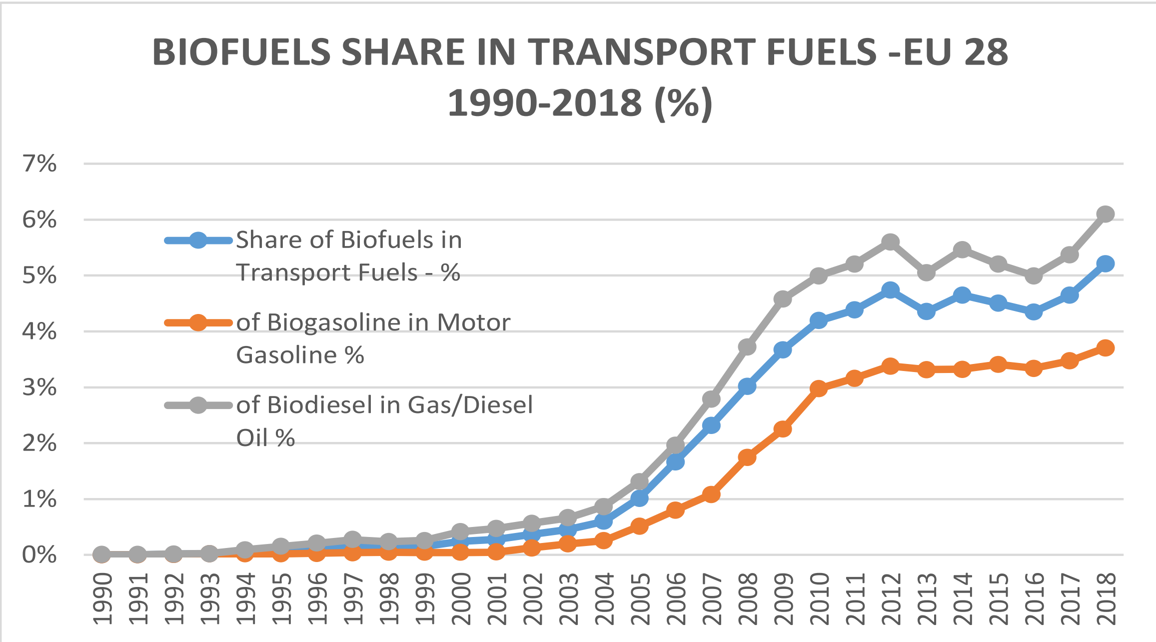

Figure 5. Development of biofuel shares. Data from[37].

In 2018, the total amount of biofuels consumed was 16.6 Mtoe, representing 5.2% of the total consumption transport fuels. Absolute volume of liquid components for petrol was 3.0 Mtoe and for diesel 13.7 Mtoe[33].

In 2018, the consumption of fossil petrol and diesel was in total 288 Mtoe. Volumes for gaseous fuels in transport were 6.0 Mtoe for LPG and 3.6 Mtoe for natural gas[33]. According to the Biofuels Barometer, the amount of biomethane was some 0.15 Mtoe in 2017[38]. It is projected that 40 % of the methane used in transport in 2030 could be biomethane[39].

[36] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN
[37] https://ec.europa.eu/energy/data-analysis/energy-statistical-pocketbook_en
[38] https://www.eurobserv-er.org/biofuels-barometer-2019/
[39] https://www.ngva.eu/wp-content/uploads/2020/06/EBA_NGVA-Europe_TheEuropeanGreenDeal_FastLaneTransport_20200615_spread.pdf

The International Energy Agency (IEA) is tracking progress in clean technologies on the world level, including biofuels in the transport sector. The 2019 report "Tracking transport[40]" states:

"Transport biofuel production expanded 6% year-on-year in 2019, and 3% annual production growth is expected over the next five years. This falls short of the sustained 10 % output growth per year needed until 2030 to align with the Sustainable Development Scenario (SDS). Stronger policy support and innovation to reduce costs are required to scale up both advanced biofuel consumption and the adoption of biofuels in aviation and marine transport."

Then message from IEA is that biofuels volumes should triple by 2030 compared to 2020 to match sustainable development (Figure 6), and that the projected development in the period 2020 - 2025 is by no means sufficient.

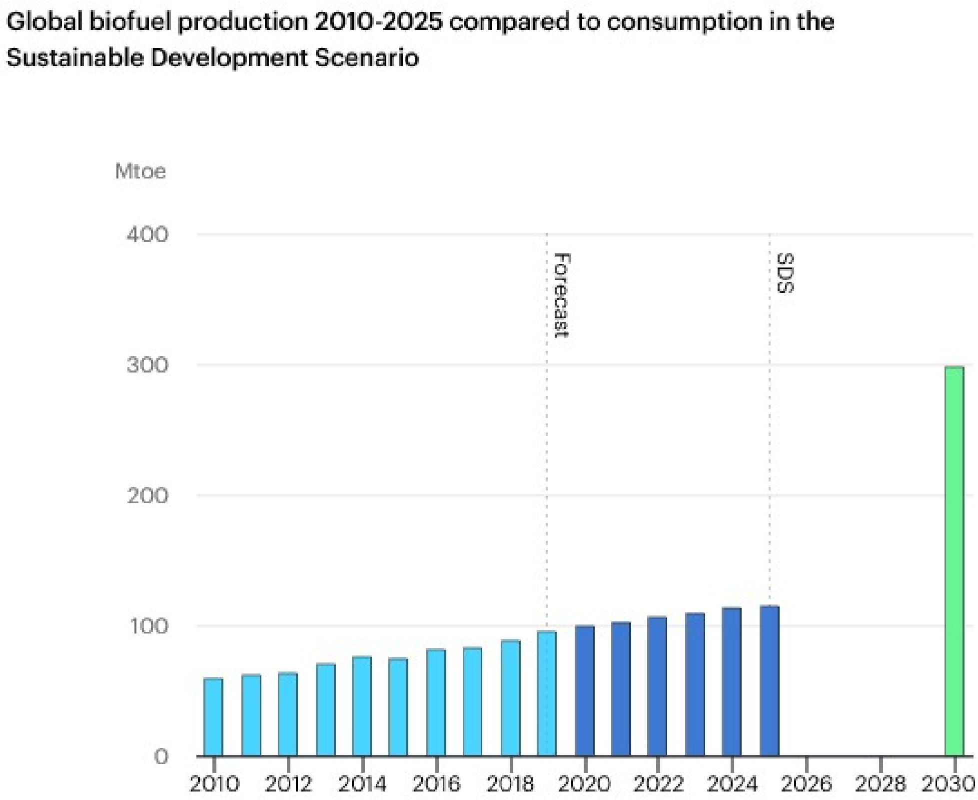

Figure 6. Projected growth in global biofuel volumes and the need for biofuels in 2030[21].

Within EU, Sweden and Finland have ambitious targets for emission reductions in transport. Sweden aims for a 70 % reduction in transport CO_2 emissions by 2030 (reference year 2010)[41], and Finland aims for a 50 % reduction in 2030 (reference year 2005)[42]. Neither of these targets can be reached without a significant portion of renewable fuels. However, in the European context, the fuel volumes in these two countries are small. In 2017, the total EU consumption of road transport fuels was 304 Mtoe. Consumption in Sweden was 7.8 Mtoe (2.6 % of EU total) and 4.0 Mtoe in Finland (1.3 % of EU total).

[40] https://www.iea.org/reports/tracking-transport-2019/transport-biofuels
[41] https://www.trafikverket.se/for-dig-i-branschen/miljo---for-dig-i-branschen/energi-och-klimat/Klimatmal-for-transportsektorn/
[42]https://tem.fi/documents/1410877/2769658/Government+report+on+the+National+Energy+and+Climate+Strategy+for+2030/0bb2a7be-d3c2-4149-a4c2-78449ceb1976/Government+report+on+the+National+Energy+and+Climate+Strategy+for+2030.pdf

Figure 7 shows the Swedish biofuel volumes in 2005 - 2018. Sweden actually represents some 10% of the total EU biofuels consumption. Sweden uses a combination of a CO2 reduction obligation for petrol and diesel, meaning low-level blending of bio-components in regular fuels, and tax exemptions for high level biofuels (E85/ED95, B100, HVO100, biomethane).

The current 2011 - 2020 Finnish biofuels obligation (liquid biofuels) calls for 20% biofuels in 2020, taking into account double counting for advanced biofuels. In spring 2019, the biofuels obligation was revised, and the pathway towards 2030 was set, written in law. The biofuel target for 2030 is 30%, and this time actual energy contribution without double counting. There is also a separate sub target for advanced biofuels, 10%, i.e., one third of the total contribution[43].

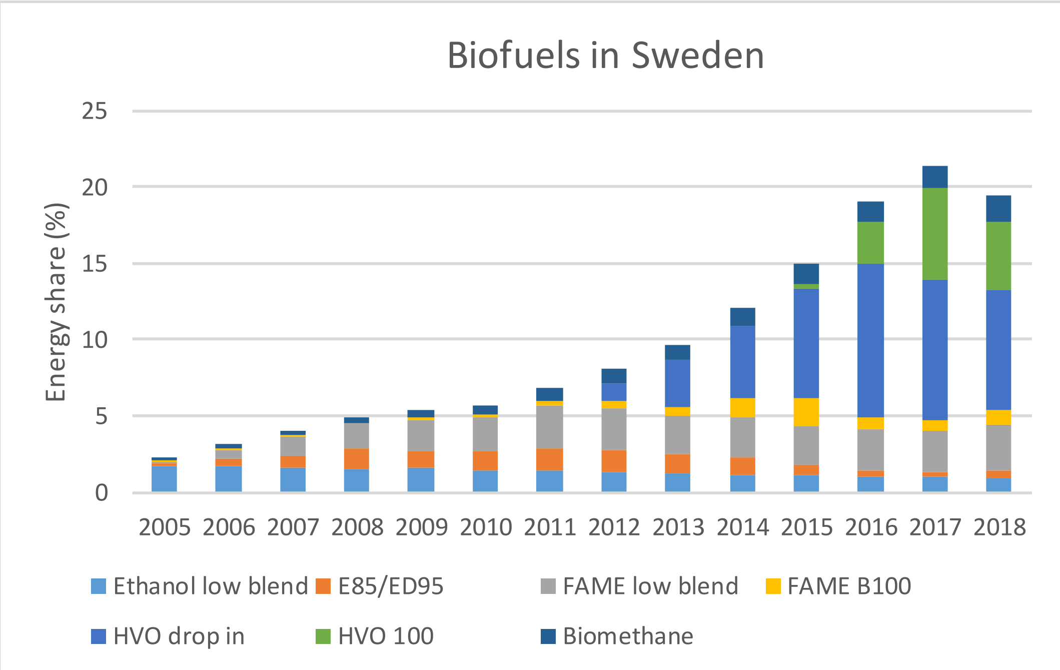

Figure 7. Biofuels in Sweden (data from[44]).

Costs for CO2 reduction

Most technologies for CO_2 reductions in transport, whether vehicle or fuel related, come with a cost. Overall costs are made up of investments or additional costs for the vehicle, infrastructure and operational costs (fuel and maintenance).

In 2016, the German consultancy Roland Berger carried out the study "Integrated Fuels and Vehicles Roadmap to 2030+"[45]. The study aims to provide an integrated roadmap taking into account the feasibility of all fuel and vehicle technologies along with infrastructure needs and the recommended policy framework beyond 2020. A key consideration was to identify a roadmap with the lowest, achievable GHG abatement costs to society.

Figures 8 (light-duty vehicles) and 9 (medium- and heavy-duty vehicles) summarize CO_2 abatement costs. The projections are for 2030. According to Roland Berger, the most cost-effective technologies for

[43] https://www.finlex.fi/fi/laki/alkup/2019/20190419
[44] https://spbi.se/statistik/andel-fornybart-i-transportsektorn/
[45] https://www.rolandberger.com/ru/Publications/Integrated-Fuels-and-Vehicles-Roadmap-2030.html

passenger cars up till 2030 are biofuels and hybridisation, for medium- and heavy-duty vehicles the most efficient options are biofuels and increasing vehicle size. Actually, the latter has a negative cost.

CO_2 abatement though the use of biofuels is estimated at some 100-200 €/tonne CO_2. Roland Berger estimates the costs for CO_2 abatement through electrification (battery electric vehicles) at some 200-600 €/tonne, depending on application and range.

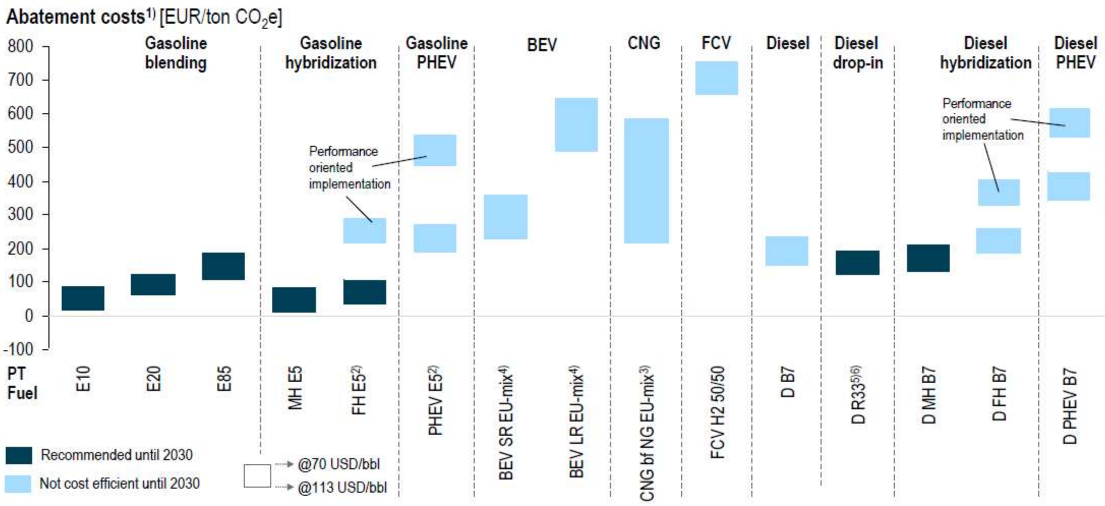

Figure 8. CO_2 abatement costs for passenger cars (C segment)[26]. Please note that the figures for methane (CNG) are for fossil natural gas, not biomethane.

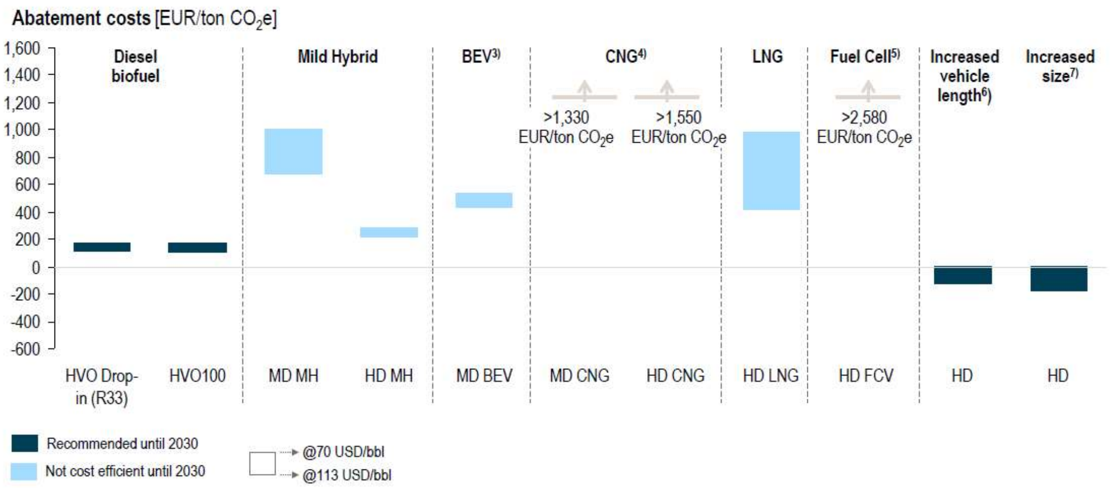

Figure 9. CO_2 abatement costs for medium- and heavy-duty vehicles[26]. Please note that the figures for methane (CNG, LNG) are for fossil natural gas, not biomethane.

Particularly the heavy-duty sector is very cost sensitive. Currently, renewable fuels are more expensive than fossil fuels. So far, renewable fuels have been brought to the market either though mandates or tax incentives to support environmental objectives. Increasing price on CO2 as well as technical development in renewable fuel processing will increase the competitiveness of renewable fuels over time.

The IEA Technology Collaboration Programme Bioenergy has recently (2020) released a study "Advanced Biofuels – Potential for Cost Reduction"[46].

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[46] https://www.ieabioenergy.com/wp-content/uploads/2020/02/T41_CostReductionBiofuels-11_02_19-final.pdf

Figure 10 shows the impact of learning on costs of advanced biofuels, and projections for fossil fuel and carbon prices. In the figure, capacity increases by a factor of 10 and 100 and learning rates of 0-20% are built in. The message here is that with growing capacity and improved technology the price of advanced biofuels will eventually fall between the current fossil fuel price level and the anticipated future fossil fuel price with increased price on CO_2.

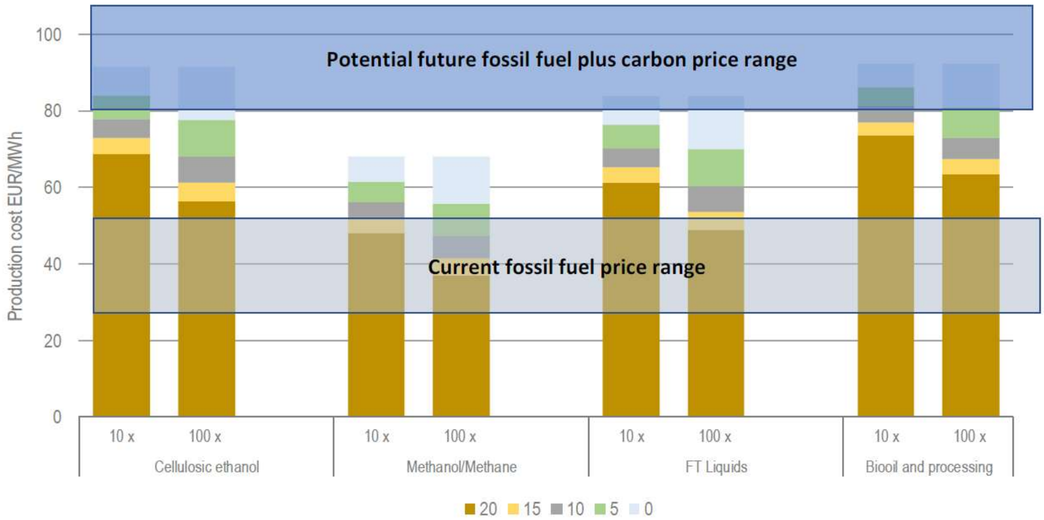

Figure 10. Impact of learning on costs of advanced biofuels, and projections for fossil fuel and carbon prices.

What Is needed for increased uptake of renewable fuels in road transport?

To make an increased uptake of renewable fuels in transport possible, the following important conditions have to be fulfilled:

- A **stable legislative framework** that recognizes and rewards renewable fuels in accordance with their potential to reduce fossil GHG emissions. This is important for vehicle related legislation as well as legislation on fuels. The GHG/efficiency legislation should be based on well-to-wheels (WtW) analysis.
- **Adequate long-term supply** of renewable fuels with good CO_2 reduction potential must be secured and the vehicle buyers should be able to fully trust that.
- **Fair CO_2 pricing**
- **The total cost of ownership (TCO) of alternative fuelled vehicles should be closer to that of the corresponding fossil-fuelled counterpart** and, for truck and bus buyers particularly, the second-hand value 3-5 years down the road has to be predictable and reasonable.
- **It should be attractive for vehicle OEMs to produce and promote alternatively fuelled vehicles**. The vehicle CO_2-legislation should support and reward these vehicles/fuels in accordance with their overall GHG reduction potential. To create a level playing field between fuels containing fossil and biogenic carbon, and between biogenic carbon containing fuels and 'carbon free' energy carriers (e.g. electricity, hydrogen), **a full WtW approach should be applied for all conventional and alternative value chains.**