ARTFuels

NARRATIVE

TRANSPORT IS THE #1 EMITTING SECTOR IN EUROPE (WITHIN THE NON-EU ETS SECTORS)

Mobility is an essential part of our lives. Cycling and walking are becoming more popular, but this doesn't mean we are using less cars, ships, trains, trucks and planes to move around ourselves and goods. Whatever mode of transport energy is used, it goes hand in hand with all sorts of emissions. And this demand for energy in transport has a strong impact on the concentration of greenhouse gas emissions in the atmosphere[1].

In the EU transport is almost entirely dependent on fossil fuel and the expectation is that this will still be 90% in 2030[2]. The transport sector, including aviation, is compared to other economic sectors like power, industry, agriculture, buildings the only sector that has not been able to curb its CO2-emissions[3]. As a consequence, it has become the number one GHG emitting sector in Europe (within the non-EU ETS sectors)[4].

Since transport is essential, we must deploy all solutions to reduce GHG emissions and accelerate the transition from the use of fossil-fuels /oil to renewable and low-carbon based sustainable (re)sources.

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[1] *(>400ppm; https://www.noaa.gov/news/global-carbon-dioxide-growth-in-2018-reached-4th-higheston-record)*

[2] SWD(2016)418 final, Impact assessment for the REDII proposal, page 237.

[3] Greenhouse gas emissions from transport continue to rise, and in 2017 were 20% higher than in 1990, COM(2018)733, page 22.

[4] https://www.eea.europa.eu//publications/european-union-greenhouse-gas-inventory-2019

MANY SOLUTIONS ARE NEEDED TO DECARBONIZE TRANSPORT

There are many measures that can be deployed to address the growing (fossil) energy demand and associated greenhouse gas emissions: increased efficiency, engine CO2-standards, modal shifts from the road to rail and water, but also increased use of public transport, more walking and cycling, change in powertrains/engines that can run on for example electricity or hydrogen/fuel cells made from renewable sources (power-to-X).

Still, these solutions are not sufficient to address the climate impact of transport and to achieve the substantial impact required immediately. We also need to continue to use low carbon liquid and gaseous fuels to decarbonize existing fleets as well as for those transport modes that cannot (yet) or are difficult to electrify like heavy duty transport such as longdistance trucks and buses, shipping and aviation.

THERE IS NO SILVER BULLET; ALL SUSTAINABLE SOLUTIONS MUST BE DEPLOYED IN SYNERGY

The transport sector is complex given the different modalities and the way we use transport in our daily lives. This complexity makes it impossible to find a one-size-fits-all solution to curb emissions. Fleet renewal takes time and not all transport segments can be electrified in the short and medium term. Yet, there is general agreement among policymakers that it is a top priority to reduce GHG emissions in transport. The EU should explore all (existing and new) low-impact options to provide environmentally sustainable mobility so that the impact of the measures deployed can be maximized.

The challenge is to combine all measures at hand in the most effective way; that serves society and customers best to achieve mobility that is the lowest CO2-intensive over the entire lifecycle at low/affordable costs and without dispute sustainable. The EU is globally leading the way when it comes to setting sustainability standards for the use of bioenergy and biofuels. These standards have a positive impact on sustainability practice in agriculture, provide prospects for rural development for reducing land abandonment, improving soil quality and reactivating degraded land all over the world. And, let's not forget the knock-on effect of these standards in other sectors like food/feed production or forestry.

ALTERNATIVE RENEWABLE TRANSPORT (ART) FUELS[5] ARE AVAILABLE AND GROWING

The biofuel industry, globally but also at EU level, has already undertaken a major effort to innovate and develop low carbon renewable liquid and gaseous transportation fuels. At the same time, we see that major players in the oil industry are shifting towards the use of more sustainable biofuel also in the production of conventional fuels. Several sustainable technologies have been developed and are now steadily being scaled up[6]. There are very promising technologies but building production capacity up to the level that these fuels create the necessary impact and are affordable is challenging as the environmental costs linked to the use of fossil are still not reflected in the price paid by consumers/customers. Moreover, as long as the use of fossil fuel keeps being subsidized there cannot develop a level playing field. Achieving an economy of scale of ART fuels requires a fundamental change in government policy on subsidizing and taxing energy products.

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[5] *These are sustainable liquid or gaseous fuels from a broad range of renewable and/or waste-based feedstock.*

[6] *See the annexes on the various technologies and the state of the development thereof.*

MORE AMBITION IS NEEDED

Both more renewable fuels (liquid and gaseous) and electricity will require further large investments, also in infrastructure. Not only because the new technologies have to become competitive with mature fossil fuel technology but also because large volumes of fossil fuels need to be replaced in a relatively short period.

Oil had more than 150 years to optimize; we have three decades left to transform and become carbon neutral by 2050. This transition can only happen with ambitious policies that are aligned with the Paris Agreement (i.e. main well below 2 degrees global warming) not based on what we think is feasible but based on what we know is needed.

Governments can support the necessary deployment of ART fuels in different ways. Providing funding for innovation and to bridge the valley of death is of critical importance. Equally important is developing policy that is stable and long-term that can deliver the boost needed whilst ironing out the lack of level playing field with fossil fuels by abolishing subsidies and introducing a fair and honest taxation system on energy products.

THE ART FUELS FORUM IS WILLING TO CONTRIBUTE

The Alternative Renewable Transportation Fuels, in short ART Fuels Form or AFF, was set up in 2017 and brings together more than 100 experts providing decisionmakers and regulators with the latest state-of-play and progress on alternative fuels.

The AFF wants to provide advice to decisionmakers in what way policy could be further improved to achieve the set targets decarbonizing transport. And at the same time providing national legislators and regulators with guidance how best to transpose the REDII to obtain the best possible result for the entire Union.

FOR FURTHER READING

For those that are interested to learn more on alternative fuels, the technologies behind these fuels, where these are being researched and applied and what alternative fuels can mean for various policy areas outside the transportation sector there are a number of annexes attached to this document. More information can also be found at: www.artfuelsforum.eu

POLICY RECOMMENDATIONS

The time-frame 2020-2030 is crucially important for delivering on the 2050 objective. This decade needs to lay the foundation to build a stable and large-scale European industry for the production of alternative renewable Transport fuels. Constructing this foundation requires a variety of focus areas with the following policy measures:

- **Ambitious and consistent implementation of REDII but technologically neutral**
  - To avoid internal market distortion for alternative transport fuels a consistent andcoherent transposition into national law of Directive 2018/2001 is essential.
  - Targets should be technologically neutral: all options are needed to achieve the-goal of the Paris Agreement.
  - All sustainable biofuels should be accepted for achieving targets.
- **Value for sustainability/ GHG saving and performance**
  - A fair excise (taxation) scheme on fuel in which taxation will be based on CO2-performance and energy content; the volume-based system is outdated and is advantageous for fossil fuel only.
  - Emissions of every energy source should be measured on a well-to-wheel basis to ensure GHG savings are calculated with objective and non-discriminatory criteria across all technology options.
  - A complete -phase out of subsidies for fossil fuel.
- **Financing and funding**
  - Within the relevant financial instruments, like the Innovation Fund, priority should be given to the development of the still capital-intensive industry of alternative transportation fuels.
- **Higher blends are needed**
  - Sometimes blending-in higher levels of alternative fuels are not possible due to lacking standards. EU legislation should be adapted to allow for higher ethanol (E20) and bio-diesel (B10) blends.
- **Post 2030**
  - The EU should set ambitious targets for the use of advanced renewable fuels post 2030. Ideally a bi-annual trajectory to be adopted. There should be no back-trackingfrom the 2030 target.

Below are listed policy recommendations related to particular sectors and fuels

- **Heavy Duty vehicles**
  - Proper recognition of biofuels and other 'low-CO2' fuels in the Heavy-Duty CO2 directive. The test fuel regulation and VECTO simulation tool should be updated by adding alternative fuels listed in AFID/DAFI to the list of 'reference fuels'. Where paraffinic fuels (HVO100, GTL) and high-octane gasoline the most urgent to be added in order to give OEMs incentive to optimise engines for these climate-friendly fuel options.
  - Adequate quality requirements for fuels and fuel-blends that are put on the EU market. This can be handled through legislation (for instance FQD 2009/30/EC) and/or via the European standardization process (CEN).
  - The economic conditions must be acceptable for the transport companies. Buying alternatively powered vehicles has to be "low risk" projects and the running costs have to be predictable over their full useful life, as well as their expected second-hand value after 3-4 years.

- **Aviation fuels**
  - A separate, tailor made policy approach for the aviation sector in light of international competition, existing international agreements on carbon reduction and more stringent fuel quality needs than in other transport sectors.
  - A European mandate for SAF, with strong sustainability safeguards and alignment on carbon accounting methodology with international agreements (e.g. the carbon reduction program of the United Nation's International Civil Aviation Organization).
- **Power-t-X / e-fuels**
  - A fair competition between technologies requires a level playing field on sourcing and sharing of renewable electricity, subsidies and multipliers. For more details go to **https://bit.ly/2XP9AMi** .
  - Recognise Power-to-X as an advanced renewable fuel.
- **Biomethane**
  - International transport of biomethane should be free of hurdles, i.e. guarantees of origin have to be introduced.
  - The European LNG strategy (2016) should be revised to incentivize the deployment of liquified biomethane to gradually replace fossil LNG. A blending target of 10% for LNG suppliers should be introduced EU-wide.
- **Lipid and Algae based biofuels**
  - A blend of 10% biodiesel (B10) should be rolled-out across Europe as normal diesel grade under EN 590 diesel standard.
  - New revision of Fuel Quality Directive should take into account high blend biofuels (such as fuels listed in Alternative Fuels Infrastructure Directive).
  - Sectorial mandates should be set for higher biofuel blends (e.g. B30, B100 and HVO100) in transport modes where electrification is less feasible such as captive fleets, public transport, Heavy-Duty Vehicles, Aviation and the Maritime sectors; increasing the share of renewables in the heating sector should also be looked at due to high potential for GHG emissions savings.
  - The test fuel regulation and VECTO simulation tool should be updated by adding alternative fuels listed in AFID/DAFI to the list of "reference fuels". Where paraffinic fuels (HVO100, GTL) and high octane gasoline the most urgent to be added in order to give OEMs incentive to optimise engines for these climate-friendly fuel options.

ANNEX I: DATA ON ADVANCED BIOFUEL PRODUCTION WITHIN THE EU

The overall EU biofuel production accounted for 15,300 ktoe in 2017[7], to which advanced biofuels (Annex IX part A) contributed at least by some 203 ktoe. Based on estimations, it is noted that the overall EU biofuel production corresponds to approximately 29 million passenger cars.

The 2018 global HVO Renewable Diesel estimated production capacity (both conventional and advanced) corresponded to ~4,700 ktoe. The majority of the product is sold in the EU. The global production capacity is expected to increase to around 11.4 million tonnes, by 2022, from the announced projects including both new dedicated refineries as well as retrofits not initially designed for renewable feedstock. In the EU, HVO production was approximately 2,028 kton in 2017.

As regards ethanol, in 2017 the production of EU ethanol from lignocellulosic feedstock/ other REDII-Annex IX/other feedstock accounted for 198.5 kton, according to ePURE data collected among its members[8]. It is estimated that in the same year, at EU level, 39.7 kton of advanced lignocellulosic ethanol had been produced by a number of small-sized demo and commercial scale plants, located in several EU countries[9, 10].

In 2017, approx. 198 kton of advanced biodiesel/renewable hydrocarbons (mostly supplied by two commercial plants based in Finland and Sweden)[11] were produced, out of approximately 11.6 Mton of total biodiesel and hydrotreated vegetable oils and lipids (HVO) production (which includes double counted Annex IX-B feedstocks)[12].

In 2017, ~240 Mm^3 of biomethane were used in transport in EU, which included both conventional and advanced feedstocks[13]. Germany is responsible for 75% of the total EU production, with an average of 90% of it based on waste and residues; Sweden is the second largest producer of biomethane in the EU, and by far the largest national gas-powered transport market, since more than 75% of its biomethane is used in the transport sector[14]. There were just above 500 operating plants in 2017, where biogas is upgraded to biomethane; 200 of them are placed in Germany, almost 100 in the UK and 65 are based in Sweden[15].

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[7] *Eurostat, SHARES tool 2017. Available at: https://ec.europa.eu/eurostat/web/energy/data/shares*

[8] *ePURE, European renewable ethanol - key figures 2017, 2018. Available at: https://www.epure.org/media/1763/180905-def-data-epure-statistics-2017-designed-version.pdf*

[9] *Biofuture Platform, Creating the Biofuture: A Report on the State of the Low Carbon Bioeconomy, (2018) 2018. Available at: http://biofutureplatform.org/resources/*

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[11] *I. Landälv, L. Waldheim, K. Maniatis, Continuing the work of the Sub Group on Advanced Biofuels - Technology status and reliability of the value chains: 2018 Update, 2018.*

[12] *European Biodiesel Board Statistical data. Available at: http://www.ebb-eu.org/stats.php*

[13] *EBA and NGVA data*

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[15] *I. Landälv, L. Waldheim, K. Maniatis, Continuing the work of the Sub Group on Advanced Biofuels - Technology status and reliability of the value chains : 2018 Update, 2018.*

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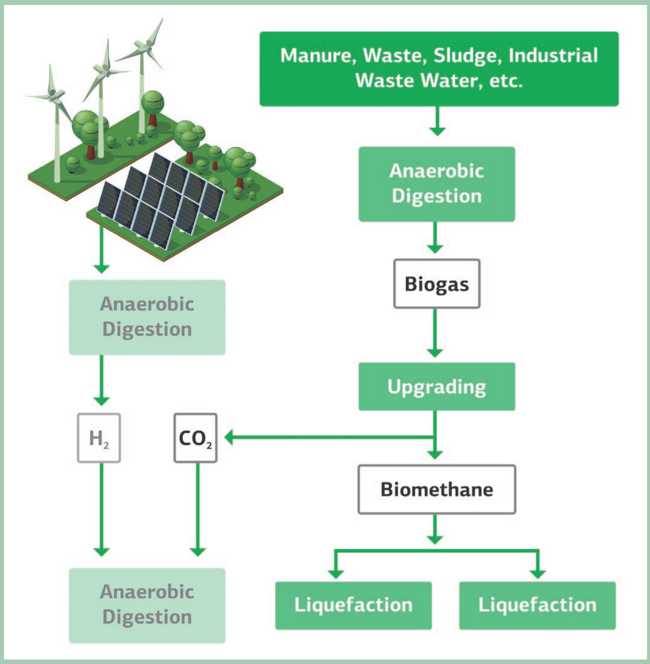
1 | BIOMETHANE

TECHNOLOGY PATHWAYS

Biomethane is the general term for all gases produced from biomass whether it is through gasification, power to methane (P2M) or anaerobic digestion (biogas). In this section we concentrate on Anaerobic Digestion (AD) while the other two processes are described elsewhere. However, it should be pointed out that biomethane from AD can be favourably combined with P2M to produce more renewable methane as shown in the graph below. Today, some 85% of the biogas is used for the production of heat and power however, upgrading to biomethane is an increasing application. By the end of 2017, 540 biomethane plants were operational in 15 countries throughout Europe (EBA). Germany has the most plants (195), followed by the UK (92) and Sweden (70). Some additional 60 to 100 plants are in operation in the rest of the world. In Europe, roughly 2 billion m3 of biomethane were produced corresponding to 20 TWh or 1.7 mtoe. Biomethane covers today about 15% of the gas transport market (NGVA). This will increase significantly with the new heavy-duty vehicles (HDV) entering the market with more than 400 HP engines and able to run up to 1600km with one filling. Also, the potential application of biomethane in passenger cars and light duty vehicles (LDV) is significant with more than 2 mio gas vehicles on Europe's road. The European Biogas Association (EBA) and the Natural Gas Vehicle Association (NGVA) are expecting an increase of gas vehicles coverage of up to 33% for buses, 25% for HDV and 12% for passenger cars until 2030.



More recently, liquid biogas (LBG) started to be used in maritime transport particularly in ferry boats but also in cruise ships in combination with natural gas (LNG) reducing CO2 emission but even more controlling pollution of sulphur, NOx and particles. In fact, the number of gasdriven ships on order in 2018 (132) is higher than the actual number of operated vessels (121).

PROJECTS AND INITIATIVES

Today, most of the biomethane is produced from waste material e.g. from agriculture, source separated and industrial wastes. The production is strongly growing especially in the countries with well-defined biomethane targets, i.e. CH, DK, FR, IE, IT, NL and SE. The potential of AD from waste is still considerable. Even more promising is the utilisation of secondary crops which not only increases biogas production but also avoids fallow land and reduces emissions of nitrous oxide and ammonia. At the same time soil carbon is increasing thanks to the application of digestate. Food and fuel can be grown sequentially on the same ground within a growth period.

On top, addition of hydrogen from P2G to the separated CO2 from the biomethane upgrading process could alone double the amount of biomethane without a single new plant. Once the excess renewable electricity from P2G is systematically used and the construction of gasification plants is taking off, the production will be multiplied.

ADVANTAGES OF BIOMETHANE PRODUCTION AND CHALLENGES

Biomethane is an all-purpose energy source replacing increasingly natural gas by using the same infrastructure. It not only helps decarbonising transport on road and water but at the same time upgrades wastes to sustainable fertiliser, helps reducing GHG in agriculture and is sequestering CO2 while building up soil carbon. Biomethane plants are a mature technology for decentralised units. They are getting close to be economically viable under condition that waste feedstocks delivered to a biogas plant pay a reasonably high gate fee of 30 to 50 EUROs per ton and biomethane is free of tax. The limiting factor is the size as today the plants need an installed capacity of minimum 1.2 MW (approx. 250m3 biogas per hour) while most of the biogas production takes place in smaller units. LBG plants need to be at least two times this size. However, the development of smaller LBG units has just started.

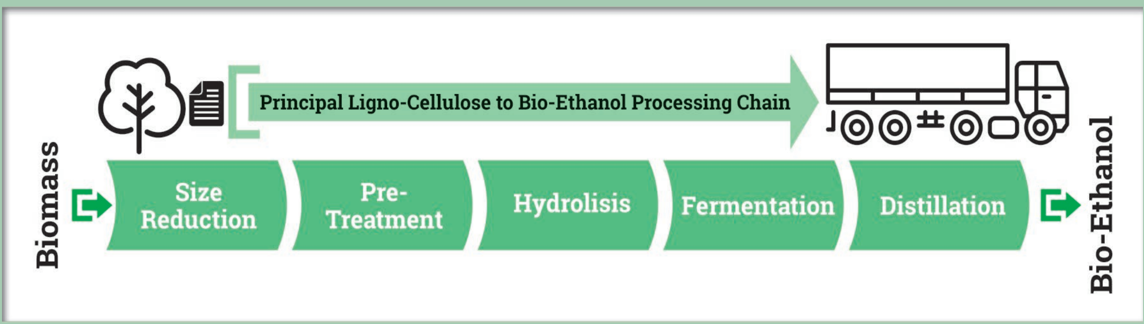
FURTHER READING

- **IRENA technology brief: Biogas for road vehicles**
- **EBA: Biomethane in transport, Statistical Report 2018**
- **NGVA: Statistical report 2017**
- **Gas for Climate study 2019**

2 | CELLULOSIC ETHANOL

CELLULOSIC ETHANOL

Cellulosic ethanol is produced from lignocellulosic biomass from forestry, agriculture and other industries (e.g. forestry residues, straw, bagasse). Lignocellulosic materials are included in the list of Annex IX-A of Directive 2018/2001, therefore cellulosic ethanol qualifies as Advanced Biofuel in the EU. The following processing steps may be found in a general lignocellulose to renewable ethanol production processes: Cellulosic ethanol is currently mainly being deployed in China, Europe, India, Brazil and the US. There is one industrial plant operating at commercial scale in Europe and producing cellulosic ethanol as the main product, owned by Versalis in Italy. St1 in Finland, on the other hand, is a demo unit and Borregaard in Norway is a high purity lignin plant that produces ethanol as by-product. Other projects are under construction and development: in Romania and Poland (Clariant), in Slovakia (Enviral/Clariant and Energochemica), Norway and Sweden (St1) and in Finland (Nordfuel/Sekab and St1). There are other plants in



operation in the world (Raizen and Granbio in Brasil, POET-DSM in USA, Henan and Shangdong Long Live in China) and 6 plants planned and under construction in India.

Cellulosic biomass is available. Multiple studies agree that the sustainable primary biofeedstock potential (using a food/fiber first principle) will be more than 2388 MTOE/y by 2050 (Creutzig et al. 2015). In their bioenergy roadmap, the IEA (2017b) assumes a range of 131 to 240 EJ of sustainable biomass resource could be available by 2060. For the two and below two degrees' scenarios, IEA estimated a requirement of 145 EJ of sustainable biomass resources.

Based on input from key technology providers, E4tech developed in 2017 scenarios for cellulosic ethanol deployment in the EU from 2021 to 2030. The central scenario concluded that 46 plants could be built by 2030 in Europe and could produce around 2.75 billion litters of cellulosic ethanol. This is equivalent to an estimated 4% blend of cellulosic ethanol in gasoline by volume by 2030.

Each project brings a stimulus of agronomic research, agricultural activities and logistic distribution with the creation of new opportunities of economic and social development of the local territory, creating jobs and developing an industrial platform that can foster further growth. Even if in future, electrification of passenger transport is increasing, there will still be a need for low-carbon liquid fuels. Also, green carbon in the form of hydrocarbon feedstocks will be in high demand for chemicals and materials. The best way to make sure those feedstocks are competitive in the long term is to use and facilitate the power of scale from low-carbon fuel technologies today.

In addition to the mandatory quota for advanced biofuels, which has to be transposed together with penalties for non-compliance/incentives to encourage compliance and which is essential for creating stable framework conditions, the widespread use of advanced biofuels should be supported by a series of accompanying measures, adapted to the national conditions:

- Support for new supply chains is the basis for cost-efficient raw material supply, e.g. though the CAP.
- Fuel taxation ensures fair competition.
- Promotion of research, development and commercialization with a view to further optimize technology, process integration and to reduce costs.
- The need for investments in replication via grants or loan guarantees using existing public funding and financing tools (Structural Funds, EFSI, EIB, etc) to leverage and de-risk private investments.
- Deploy E10 in all Member States, offer higher blends at the pump and standardize new mix-blends of ethanol in petrol (E20/25) in order to maximize the contribution of renewable ethanol to climate target.❖

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3 | HVO & FAME

HVO & FAME

The common acronym HVO comes from 'Hydrotreated Vegetable Oil' or 'Hydrogenated Vegetable Oil'. The terminology originates from last decade when only vegetable oils were used as feedstock. Today more and more of HVO is produced from waste and residue fat fractions coming from food, fish and slaughterhouse industries, as well as from non-food grade vegetable oil fractions. Thus, HVO and 'Hydrotreated Vegetable Oil' are no longer accurate terms describing the origin of the fuel. However, those terms cannot be changed easily since they are common in the European regulation, fuel standards, and biofuel quality recommendations set by automotive companies. According to several chemistry experts 'Hydrotreated' referring to fuel processing should be preferred instead of 'Hydrogenated' as the latter is commonly linked to manufacturing of margarine.

'Renewable Paraffinic Diesel' has also been commonly used as it is chemically a proper definition for product quality. However, this term covers also pilot scale Biomass-to-Liquid (BTL) fuels made by Fischer-Tropsch synthesis and, therefore, does not define feedstock and process used to produce 'HVO'. Also, terms 'HDRD' i.e. 'Hydrogenation Derived Renewable Diesel', 'Non-Ester Renewable Diesel', 'Renewable Hydrocarbon Diesel', and 'HBD' i.e. 'Hydrogenerated Biodiesel' have been used especially in North America and Far East. The European EN 15940 standard uses as definition 'Paraffinic Diesel Fuel from Hydrotreatment'.

The hydrotreating of vegetable oils as well as suitable waste and residue fat fractions to produce HVO is a quite new but already mature commercial scale manufacturing process. It is based on oil refining know-how and is used for the production of biofuels for diesel engines. In the process, hydrogen is used to remove oxygen from the triglyceride vegetable oil molecules and to split the triglyceride into three separate chains, thus creating hydrocarbons which are similar to existing diesel fuel components. This allows blending in any desired ratio without any concerns regarding fuel quality.

Traditionally, diesel components produced from vegetable oils are made by an esterification process. The products are called 'Fatty Acid Methyl Esters' i.e. 'FAME' or 'biodiesel'. Other acronyms are also used, such as Rape Seed Methyl Ester' i.e. 'RME', 'Soybean Methyl Ester' i.e. 'SME', 'Palm Oil Methyl Ester' i.e. 'PME', or 'Used Cooking Oils Methyl Ester' i.e. 'UCOME'.

Both the FAME and HVO processes are similar in that they use intermediates produced from natural gas. In the future, both hydrogen and methanol could be produced from biomass or biogas. The need for natural gas is about the same in both FAME and HVO processes and is confirmed by figures published by the Renewable Energy Directive 2009/28/EC ("RED") replaced by Directive 2018/2001.

Currently biodiesel and HVO represent on energy basis 75 % of the total transport biofuel market in the EU. Global HVO Renewable Diesel production capacity in 2018 was around 4.7 million tonnes. The majority of the product is sold in the EU. The global production capacity is expected to increase to around 11.4 million tonnes, by 2022, from the announced projects including both new dedicated refineries as well as retrofits not initially designed for renewable feedstock[1].

EU biodiesel production in 2018 was 9,6 million tonnes. The imports represent additional 2 million tons. There is very little export of biodiesel[2].

The industry estimates that global availability on non-crop waste and residue material lipids suitable for biofuel production in 2030 is around 50 million tons[3]. ❖

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https://www.iea.org/tcep/transport/biofuels/

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[1] *Based on company announcements.*

[2] ***https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_7-3-2018.pdf***

[3] *Global 2030 estimation: IMCD, Oil World, Ecofys, Neste; Neste's current estimation published in Capital Markets Day 15.9.2015* ***https://www.neste.com/en/corporate-info/investors/materials***

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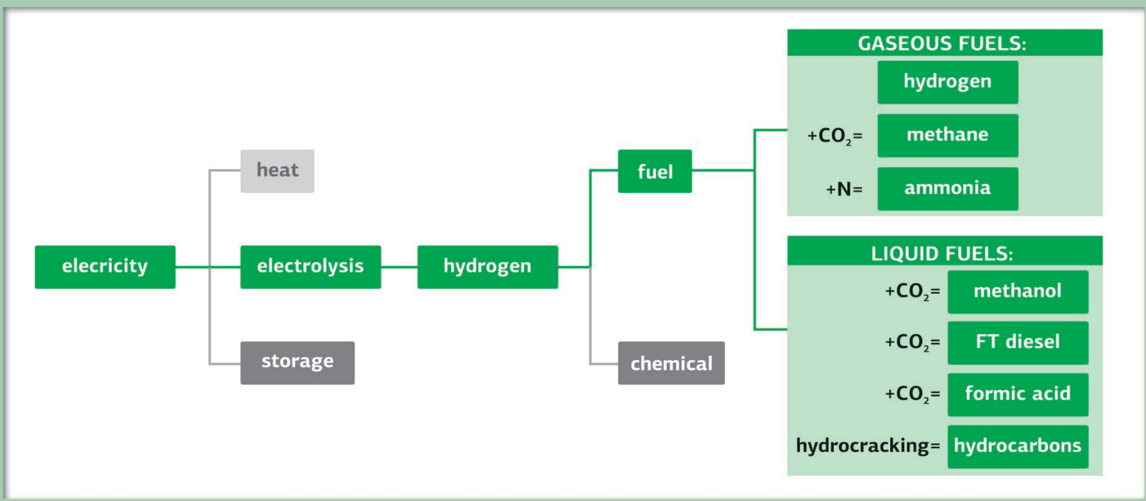
4 | POWER-TO-X

TECHNOLOGY PATHWAYS

Power-to-X - also known as **PtX** or **e-fuels** - refers to any technology which converts (renewable) electrical power to a gaseous or liquid energy carrier. The term Power-to-X is not mentioned in the Renewable Energy Directive 2018/2001. Instead the terminology 'Renewable liquid and gaseous transport Fuels of Non- Biological Origin' (RFNBO) is used. The Power-to-X concept covers many technologies and fuel pathways. Considering the need and potential to integrate increasingly higher shares of variable renewable electricity into the grid, electrolysis is used to convert electrical power to hydrogen. This allows decoupling of the energy from the electricity sector to enable its use in other sectors like road, air, marine and rail. The resulting hydrogen can be used directly as a fuel, or alternatively, reacted with either carbon (in the form of CO or CO_2 from point sources and/or air capture) or nitrogen to produce a range of different gaseous or liquid fuels, as illustrated in the examples below.



The use of PtX technology is not limited to fuels only. It enables the possibility of storing renewable electricity in a chemical form (instead of batteries). The technology can also be used to produce renewable chemicals. And when combined with biogenic processes (e.g. biomethane, ethanol) it increases the carbon efficiency of the overall process]. (when producing bio-methane or ethanol biogenic CO2 is emitted. When the carbon is captured and converted to a product it increases the yield of the amount of carbon which was used as input for the process).

PROJECTS AND INITIATIVES

Throughout Europe there is an increasing awareness around the potential of PtX, resulting in an increasing number of initiatives (some examples):

		Project	Operational
Gaseous	Hydrogen		ITM (UK)
	Ammonia	Vattenfall (NL)	
	Methane	Helmeth (GER)	Audi e-gas (GER)
Liquid	Methanol	Liquid wind (SE)	CRI (ICE)
	FT Diesel		Sunfire (GER)
	Formic Acid	Coval Energy (NL)	
	Hydrocracking	BP (NL)	
		Shell (NL)	

Provided the policy challenges listed below are resolved, it is highly likely that many more initiatives will be started in the coming decade, which would enable hundreds of millions – if not billions - of investments in the European economy, creating new jobs and allowing Europe to become less dependent on (fossil) energy imports. It is important to keep in mind that these developments are closely linked to further investments in dedicated renewable electricity production and grid improvements!

CHALLENGES

The challenges facing PtX technology to become an important corner stone of a low carbon economycan be divided into three categories:

1. Technology advancement

In terms of hydrogen production further improvements in production, efficiency and lifetime of electrolysis units will enable higher yield and lower cost.

For technologies that require carbon as an important building block efficiency and operational improvements in carbon capture (either from concentrated sources or from air) improve yield and reduce cost.

And, for the synthesis of gaseous and liquid fuels the continued development of higher efficiency catalysts further improve yield and reduce cost as well.

2. Economics

Part of the business case for PtX technologies is linked to the cost of renewable power as well as the abovementioned technology improvements to reduce cost. At the same time a value-driven demand for low carbon alternatives is required (rather than the traditional cost comparison with non-sustainable fossil fuels).

3. Policy

Supply and demand for PtX technologies and fuels is strongly connected to policy.
Unfortunately current EU policy leaves a lot of room for interpretation.

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https://bit.ly/32gciJN https://bit.ly/2JteoOc

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5 | THERMAL GASIFICATION

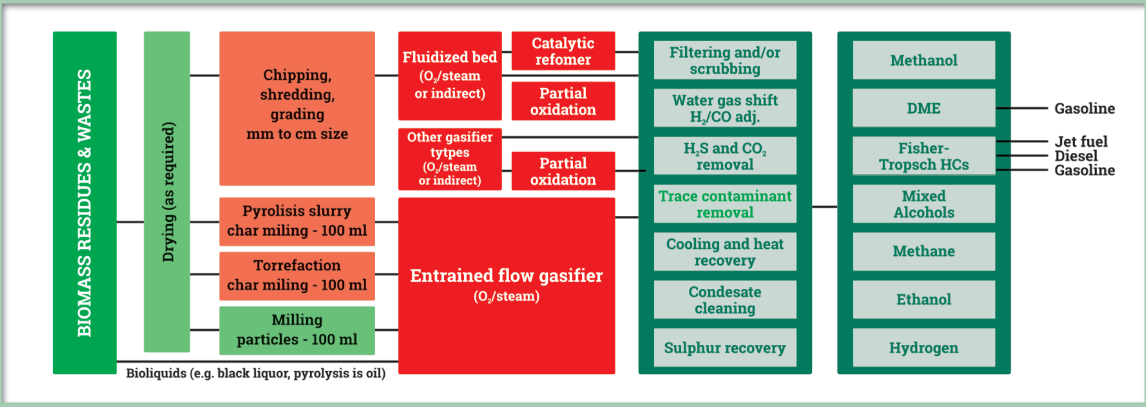
THERMAL GASIFICATION

Termal gasification is a flexible technology that can convert many types of feedstock to a variety of products via conversion to a gaseous intermediate, synthesis gas, a mixture of mainly carbon monoxide (CO) and hydrogen (H2).

The technology for the use of fossil-based syngas intermediate is well-established and has immense industrial importance in refineries and for producing many millions of tonnes of chemicals including methanol, ammonia, etc. The advanced biofuels that are possible to produce from synthesis gas include methanol, ethanol, DME, gasoline, diesel and jet fuels as well as gases such as methane and hydrogen.

THE TECHNOLOGY

The technology is in brief composed by a number of steps, see figure below. The fuel pre-treatment requires drying of the feedstock to 10-20 % moisture, if necessary, and milling/shredding and grading to particle size suitable for the type of gasifier used. This may also involve some thermal treatment to facilitate milling or conversion to a bioliquid slurry to increase energy density and facilitate feeding. Syngas production involves the feeding of the pre-treated fuel into the gasifier. In the gasifier, the fuel is converted to a raw product gas using steam and oxygen, or by steam a combined with indirect heating, respectively. Operating conditions are, depending on the process and type of gasifier from 800 up to 1500°C and pressures from atmospheric up to 30 atm. Syngas cleaning, is composed of a series of process steps at temperatures starting from gasifier temperature and going down to ambient temperature, and with integrated heat recovery. These steps initially include removal of particulates, sulphur and carbon dioxide, as well as of other contaminants and catalytic adjustment of the hydrogen/carbon monoxide ratio to suit the product. Finally, there is a compression step to synthesis pressure, if necessary. Most Biofuel synthesis systems are catalytic chemical reactions that converts the syngas to the desired product, e.g. methane, methanol, DME or Fischer-Tropsch hydrocarbons, respectively. The gas can also be converted by micro-organisms at ambient temperature to ethanol. Hydrogen can also be extracted directly from the syngas. Methanol and DME can be processed further to gasoline. Fischer-Tropsch hydrocarbon products are typically hydrotreated and then fractionated by distillation to gasoline, diesel and jet fuel. Typical energy conversion efficiency (biofuel output energy/biomass feedstock energy as received) from feedstock to advanced biofuel products ranges from 40- 50 % for drop-in hydrocarbon fuels and 60-70 % for gases and methanol. Gasification-based advanced biofuels are economically competitive with other advanced biofuels have the highest default GHG reduction factor in the RED and RED II of all pathways described.



At present, only one advanced biofuel plant is in operation, the Enerkem plant in Edmonton, Canada that produces methanol or ethanol from assorted wastes (RDF) at a nominal capacity scale of 24,000 toe/year (toe, tonnes of oil equivalents). Up to 2018, also the GoBiGas plant in Gothenburg Sweden was in operation, producing bio-methane from forest residue pellets up to a nominal capacity of 14,000 toe/year, but was closed for economic reasons (lower than expected energy prices).

There are also two plants in construction in the USA, Red Rock Biofuels and Fulcrum Sierra Biofuels that will both use the Fischer Tropsch process to produce hydrocarbons and mainly bio-jet, 45,000 toe from wood residues and 33,000 toe from RDF, respectively.

There are also two plants in planning using the Enerkem technology to produce methanol from RDF, in Rotterdam, the Netherlands, at annual capacities of 102,000 toe and Tarragona, Spain, at 123,000 toe, respectively.

FEEDSTOCK AND FEEDSTOCK POTENTIAL

Thermal gasification is very fuel-flexible, it can in principle use any reasonably dry combustible material as a feedstock. The feedstock potential for producing advanced biofuels lies in forest and forest industry residues, agricultural and agro-industrial residues as well as sorted municipal and industrial wastes (like Refuse-Derived or Solid Recovered Fuels). Hence, the potential feedstock quantities are vast, many million tonnes per year.

POSITIVES IMPACTS OF GASIFICATION INCL. BEYOND TRANSPORT DECARBONISATION

Advanced biofuels produced via thermal gasification have very high GHG reduction factors and high conversion efficiency such that the decarbonisation resulting from the feedstock resource consumed becomes high. An increased use of sustainable bioenergy feedstocks has positive socioeconomicimpacts, e.g. in employment and rural economic development.

Production of advanced biofuels/recovered fossil fuels from mixed waste fractions means improved resource efficiency and GHG reduction, relative to incineration and landfilling. Gasification technologies are very suitable for the future use of the negative GHG emission potential of BECCS, bioenergy carbon capture and storage, due to their scale and that CO2 removal is already integrated in the process.

THE MAIN CHALLENGE(S) FOR GASIFICATION TECHNOLOGIES

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INVESTING IN PRODUCTION CAPACITY

The EU SET-Plan Action 8 (https://setis.ec.europa.eu/actions-towardsimplementing- integrated-set-plan/implementation-plans) envisages advanced biofuels being produced in 50 plants of on an average 0,5 TWh each for 2022 (14 plants in operation, 16 in construction and 20 committed) and 200-250 respective plants in 2030 leading to an estimate of 10 bn € investment for 2022 and up to 60 bn € in 2030. A significant fraction of these advanced biofuel plants can be expected to be gasification plants, but the exact number is difficult to guess.

FURTHER INFORMATION

IEA Bioenergy Task 33, "Thermal gasification of biomass and wastes" (http://task33.ieabioenergy.com/) holds information and updated information on the technology. ❖

6 | HEAVY-DUTY TRANSPORT

HEAVY-DUTY TRANSPORT

The heavy-duty transport sector – trucks and buses - is the" blood stream" of our society, that is movement of goods and people. The diesel engine is the preferred power source for these commercial transport vehicles and is likely to remain so for quite some time to come, particularly for medium and long-haul applications.

The diesel engine has high energy efficiency (low fuel consumption), low exhaust emissions (particularly from Euro VI) and outstanding durability. Modern trucks are expected to last for up to 1.5 million kilometres, or even more.

Today the transport companies are operating under strict commercial and competitive conditions. Vehicle purchase and running costs must therefore be optimized/minimized to maintain adequate profitability. For a typical transport company, the fuel cost can constitute up to 35-40% of the total running costs. Therefore, to get long term acceptance for biofuels and other alternative fuels in the commercial transport sector, the fuel cost must be close to, or even on par with, the cost of the fossil fuel counterpart, mainly the regular diesel fuel. The societal goal is to drastically limit the CO2-increase in the atmosphere during the next couple of decades.

The transport sector represents a significant part of the CO2-emissions from road traffic and it is essential that this sector steps up its efforts when it comes to using fuels with low net- CO2, particularly advanced biofuels.

The newly adopted Heavy Duty CO2 directive requires truck manufacturers to reduce their average "CO2-footprint" by 15% in 2025 and by 30% in 2030, compared to 2019-2020 baseline. This is a major challenge and the 2030 target can probably only be met by maximizing the electrification in those segments where this is at all possible.

There are basically two ways to increase the overall volume of biofuels and other renewable fuels in the transport sector:

- "D rop-in" approach to conventional engines. This covers low-level blending of biocomponents into regular diesel fuel as well as certain high concentration biofuels with no or minor engine modifications. In the first case, the EU market fuel standard for diesel fuel (EN590) is followed. In the second case, even operation on 100 % renewable fuel is possible. Most current Euro VI diesels are also certified for 100 % paraffinic diesel (EN15940, e.g., HVO or Fischer-Tropsch BTL) and there are engines available which can operate on 100 % FAME (traditional biodiesel, B100).
- Dedicated engines that can use neat alternative fuels, for instance alcohols (in diesel process), methane (LNG in diesel process) or dimethyl ether. For these concepts, the technical and commercial "hurdle" may be higher, and the volume growth slower, but the reward in terms of CO2-reduction is likely to be significantly higher.

Electrification is gradually making its way also into heavy duty applications - particularly for city buses and distribution vehicles - but many types of commercial transport services are difficult to electrify. Hydrogen as transport fuel seems also to be gaining renewed interest but, also in this case, there are major challenges when it comes to production, storage and distribution of the hydrogen. There are also significant technical hurdles on the engine/ vehicle side that have to be overcome. ❖

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Heavy Duty CO2 regulation:

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7 | PASSENGER CARS

THE PASSENGER CARS FLEET

The 270 million passenger cars in the EU are responsible for around 12 % of the total EU CO2 emissions[1]. Some 55 % of the existing fleet is running on petrol, and some 40 % on diesel[2]. The share of alternative fuel vehicles (including electric vehicles) is still modest, below 5 %, the biggest category, some 3 % being gas-fueled cars (LPG and CNG, mostly bi-fuel vehicles)[3]. In driving a change in the case of passenger cars, you have to address almost as many decision makers as there are vehicles.

The share of diesel cars in new registrations peaked at some 55 % in 2011, dropping to 29.5 % in Q4 of 2019. Figure 1 shows registration figures for Q4/2019. The share of electrically chargeable vehicles (ECVs) is growing rapidly, although still at a low absolute level. The trend is expected to continue, as the increasingly stringent tailpipe CO2 emission regulation starts to kick in. The average target is 95 g CO2/km as of 2020, with further reductions of 15 % from 2025 on and 37.5 % reduction from 2030 on. To meet the CO2 targets, the auto manufacturers really need to increase production of battery electric vehicles (calculated as zero CO2 vehicles) and plug-in hybrids.

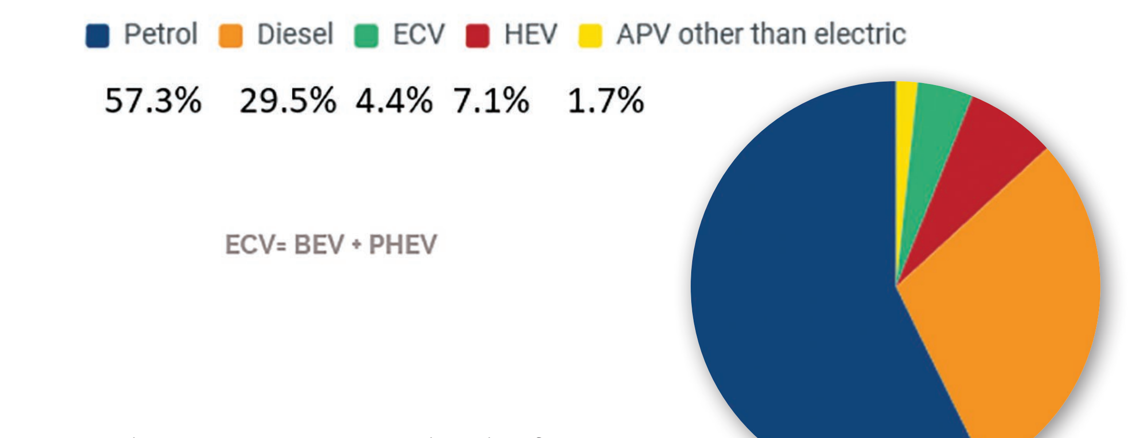

Figure 1. Passenger car registration figures for Q4/2019. Source: ACEA[4]

FUELS FOR PASSENGER CARS

Over the years, consumption of petrol has gone down, mainly due to the dieselization of the fleet. Now this trend has been broken, but on the other hand, electrification will reduce the need for petrol over time.

The road fuel consumption in the EU is some 300 Mtoe/a, of which some 17 Mtoe is biofuels (data for 2018). The volume of bio-components replacing petrol is some 3 Mtoe, contributing to some 4 % of renewables in the petrol pool and only 1 % in the total fuel pool.

The Fuel Quality Directive (FQD[6]) and fuel (CEN) standards define market fuel qualities (regular petrol and diesel fuel). Currently, the concentration of ethanol in petrol is limited to 10 % by volume (E10), for reasons related to material compatibility and mixture stoichiometry. In the case of diesel fuel, the FQD limits the concentration of conventional biodiesel (FAME) to 7 % (B7). Both E10 and B7 only deliver some 7 % of renewable energy, so additional measures are needed to increase the uptake of renewable low-carbon energy. For example, France allows B10, which has its own specific CEN fuel standard.

As in the case of heavy-duty diesel vehicles, paraffinic renewable diesel (HVO or Fischer-Tropsch BTL) in blends with conventional diesel at any concentration or even as such, constitutes a convenient and easy drop-in alternative for diesel passenger cars. However, the supply of this fuel is still limited.

To increase the share of renewables replacing petrol we need:

- E10 fully implemented in all EU Member States
- Higher concentration of ethanol/oxygenates in petrol (E10+)
- More FFVs
- More bio-naphtha type components (alternatively e-fuels)
- More methane (CNG) vehicles

According to the European Environmental Agency, E10 can be used in about 90 % of all petrol cars in Europe and in more than 99 % of the petrol vehicles produced after 2010. Notwithstanding, only some 15 % of the petrol sold in Europe in 2017 was E10, at that point available only in four countries . Now (beginning of 2020), E10 is available in 12 countries[7]. (Belgium, Bulgaria, Estonia, Finland, France, Germany, Luxembourg, Lithuania, the Netherlands, Hungary, Romania, Slovakia).

E10+ petrol has been discussed for several years. Clariant, Haltermann and Mercedes-Benz tested Sunliquid E20 in 2016-2017. A research project (2015 - 2019) financed by DG RTD and carried out by CEN/NEN concluded that E20 could be feasible. To have E20 on the market would require the FQD to be modified, a standard for the fuel as well as a reference fuel for vehicle certification. Such a fuel could be interesting for the OEMs in boosting performance, proving it would provide high octane (up to 102 RON). This is possible for new adapted vehicles only. For some part of the vehicle fleet, E20 could be backwards compatible, but without providing any additional benefits in performance.

With the introduction of Euro 6 emission legislation, new FFVs almost vanished from the new market. There are currently no real incentives for the auto manufacturers to produce FFVs, and some mechanisms are needed to incentivize multi-fuel vehicles. The additional cost for FFV technology is rather marginal, estimated at less 200 € per vehicle. With FFVs, the vehicle fleet would easily adjust to the amount of ethanol available, and blending-wall issues would easily be avoided. In France, where FFV retrofits are allowed by national legislation, FFV retrofits have gained popularity[8].

Processes for paraffinic diesel also result in side streams of bio-LPG and bio-naphta. Shares are relatively low, and bio-naphta components are additionally hampered by low octane quality. Research should aim for new renewable high-performance hydrocarbons for petrol, either bio-based or through PtX.

Cleaned-up biogas, that is bio-methane, is a drop-in substitute for natural gas. There is, however, a shortage in the supply of new methane vehicles. Volkswagen group is the only OEM manufacturer with a wide range of methane vehicles, while Fiat, traditionally strong in methane vehicles, now only offers light commercial vehicles on methane.

NEED FOR RENEWABLE FUELS AND NEED FOR HOLISTIC APPROACH

When aiming for transport decarbonisation, we need to address both the legacy fleet and new vehicles. Within new vehicles, electrification will progress rapidly both in the form of battery electric vehicles and plug-in hybrids. With renewable fuels, we can target all vehicle categories, old and new, with the exception of battery electric vehicles, and actually avoid the costly forced renewal of the vehicle fleet to decarbonize transport.

The best renewable fuels can reduce GHG emissions more than 85 % over the full fuel cycle[9]. Assessment of any energy carrier can only be correctly established if there is an approach that is based on the principle of cradle-to-grave. In fact, the assessment should even encompass the use of materials an all stages of the processes, including vehicle manufacturing and scrapping. In this wider perspective (LCA), ICE vehicles on the best renewable fuels are fully competitive with battery electric vehicle operated on renewable electricity[10].

The current vehicle CO_2 regulations consider tailpipe emissions only and not the full fuel cycle. This gives a competitive advantage for electric vehicles compared to ICE vehicles operating on renewable fuels. Consequently, the OEMs are now more focused on electric vehicles than on renewable fuels and alternative fuel vehicles.

Policy makers, throughout the system, have to be made aware that the goals for deep decarbonisation of transport simply cannot be achieved without renewable fuels; renewable fuels and electrification have to be promoted side by side (Figure 2). Within the non-emission trading sector, in which transport is the biggest contributor, some Member Countries have to reduce their CO2 emissions as much as 40 %, according to the agreement on burden sharing.

Uptake of renewable fuels could be accelerated e.g., by adjusting the FQD and fuel standards to allow more renewable components, by securing more drop-in type components for both diesel and petrol and by giving some credits to the OEMs for true multi-fuel vehicles adapted to high concentration renewable fuels

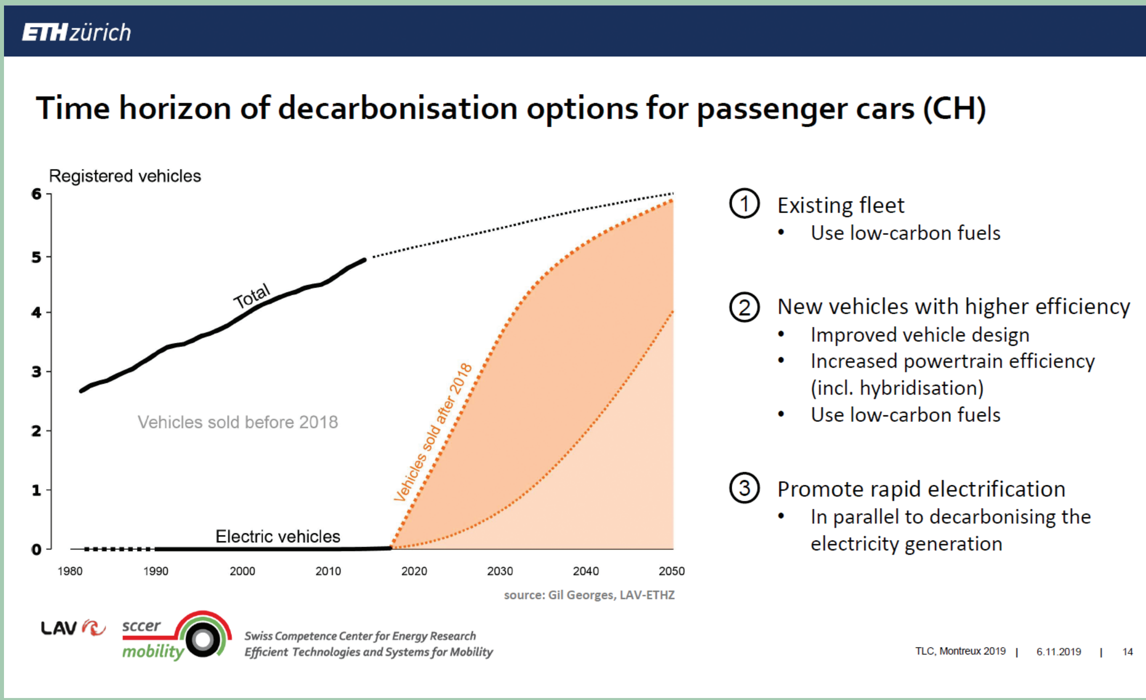

Figure 2. Time horizon in decarbonizing the passenger car fleet. Source: K. Boulouchos, ETH Zurich, 2019.

Additional reading:

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ARTFuels

8 | SUSTAINABLE AVIATION FUEL

SUSTAINABLE AVIATION FUEL

The climate challenge for the aviation industry is massive. Currently CO2 emissions for the sector are close to 1billion tons/year and with the expected growth this will double by 2050, without counter measures. Around 95% of an airline's emissions comes from combustion of fuel. Although demand side reduction, increased technical and operational efficiency and carbon off-sets are all key components of the emission reduction strategy of the sector, there is (in all of the scenarios) need for significant volumes of sustainable aviation fuel (SAF), with solid GHG performance. Current estimates are that already in 2030 Europe alone would need 10 million tons of sustainable aviation fuel to meet the sector's emission reduction targets

Since 2009, various new types of aviation fuel, based on renewable feedstock + novel technology pathways, have been approved for use in commercial aircraft operations, and multiple others are under development:

	Technology	Code	Description	Feedstock	Max blend %	ASTM
1	FischerTropsch	FT	Converts any carbon-rich material into syngas which is then catalytically converted to jet	Biomass, MSW*	50%	✓
2	Hydroprocessed Esters and Fatty Acids	HEFA	Converts oils and fats to hydrocarbons via deoxygenation with hydrogen and cracking	Oils and fats	50%	✓
3	Synthesized iso-paraffins	SIP	Ferments plants sugars to hydrocarbons which are thermocemically upgraded to jet	Sugars	10%	✓
4	FT Synthesized Paraffinic Kerosene plus Aromatics	SPK/A	Converts any carbon-rich material into syngas which is then catalytically converted to jet	Sugars, Biomass, MSW*	50%	✓
5	Alcohol to jet	ATJ-SPK	Sugars (from cellulosic materials or syngas) converted to jet through an alcohol intermediate	Biomass, MSW*	50%	✓
6	Co-processing vegetable oil	?	Vegetable oil commingled with mineral oil to produce hydrocarbons in conventional refining equipment	Oils and fats	5% (feedstock)	✓
?	Hydrotreated Renewable oil	HFP-HEFA	Converts oils and fats to hydrocarbons via deoxygenation with hydrogen and cracking	Oils and fats	? (10%)	?
?	Catalytic Hydrothermolysis Jet	CHJ	Hydrothermolysis of oils and fats into a bio-crude which can be further refind with conventional oil refining equipment	Oils and fats	?	?
?	Aqueous phase reforming	APR	Lignocellulogic material ang sugars are deoxygenated to make intermediate chemicals. These can be converted to jet	Biomass	?	?
?	Hydrotreated Depolymerized Cellulosic Jet	HDCJ	Liquefication of biomass to an intermediate biocrude, followed by conventional refining to jet	Biomass	?	?

However, despite these R&D advancements, today there is only 1 unit in the world Bostonbased World Energy (formerly AltAir Paramount) that continuously produces sustainable aviation fuel: ± 15,000 ton per year of SAF, based on the HEFA technology and waste oil feedstock. Some other companies like USA-based Gevo and Amyris are working on other technologies but are not producing at commercial scale yet.

To build more commercial SAF production units, regardless the feedstock/technology chosen, you need to raise serious investments (range: € 250M-750M). To be able to raise that amount of capital, there is need to show investors a solid market and/or guaranteed offtake contract. With all of the above possibilities, the SAF produced is more expensive than fossil jet fuel. This is partly driven by suboptimal economies of scale (vs fossil jet fuel) but also because existing government support for renewable fuels in other sectors drives up the feedstock prices.

Airlines are reluctant to pay a structural premium on their biggest operating expenditure (i.e. fuel) and are very conscious about their competitive playing field. Although the sector has shown its concrete support for and interest in the use of SAF on commercial scale, they cannot drive the development of this new market alone. Government has an important role to play as well. ❖