Facts and figures on E-fuels

Paper for UPEI's positioning

Public version

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Outline

Summary of key messages

- To bring down greenhouse gas emissions – in the context of the 2015 Paris Climate Agreement[1] to keep the world's temperature rise well below 2°C and preferably below 1,5°C – the share of renewable energy in the electricity grid and notably in the transport sector needs to increase significantly.
- The share of renewable energy also needs to increase rapidly, given the current depletion of the remaining carbon budget[2] [3].
- An increasing share of renewable electricity will be used in the transport sector. There are two clear and simultaneous modes of electricity use:
    - Direct utilisation, being electricity stored in vehicle's battery, and
    - indirectly, in which renewable electricity is used to produce a gaseous or liquid fuel that then is stored in the fuel tank of the vehicle.
- Power to Liquid (e-refining) offers a means of introducing, in an indirect way, electricity into transport, by using electricity as a source to produce e-fuels. Technology is available but requires scale up and a supportive long-term vision. E-fuels can be used in existing fuel infrastructure, thus avoiding additional infrastructure costs. E-fuels have drop-in characteristics and are fully compatible with ICE vehicles.

Key issues for e-fuels:

The following issues are viewed by studio Gear Up as of strategic relevance for the deployment of e-fuels in the transport and energy sector of Europe:

- Balancing the electricity grid
- Storage of energy
- Quick market uptake due to use in existing infrastructure and vehicles

These issues are briefly discussed below and further discussed in the report.

Balancing the Grid

With a growing share of variable renewable energy expected in the European electricity grind in the coming years and decades the need to balance the grid will become more urgent. While the grid is able to absorb variability of electricity production to a certain level, capturing the intermittency power and store it in e.g. e-fuels is an important tool for grid balancing. A growing share of variable renewable energy faces also additional market offsets, like in the transport sector.

Energy storage

Two elements are important for storage of renewable electricity: the period of storage and the volume required for storage. Liquid fuels offer unique opportunities for easy, long term, high energy density storage in existing infrastructure. Another benefit associated with this is the increased energy security, reflected in the volume

[1] https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement
[2] https://www.ipcc.ch/sr15/
[3] https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c

of energy stored in the liquid and/or gaseous infrastructure (see also Figure 27 on page 24).

Quick market uptake potential due to use in existing infrastructure and vehicles

Not only should CO2-emissions be reduced in order to prevent climate change to happen, the world community is time constraint, given the limited remaining carbon budget. Existing infrastructure for, in particular, liquid fuels exists and the majority of all vehicles still depend on such fuels. This allows an immediate market uptake, without needs for investments in new infrastructure or further vehicle technology. The possibility to introduce e-fuels in the existing logistical system and infrastructure provides an important volume-wise expansion potential. E-fuels do have on average a lower energy overall efficiency as compared to direct electricity use in battery cars. Their advantages lie in the possibility to enter the system in large volume, resulting in significant CO2-reduction potential, by re-purposing existing infrastructure. As long as electric vehicles are low in numbers on the road, their total CO2-reduction potential is limited, despite of their high energy efficiency. When BEV's become more dominant, and that is expected first in the light duty segments, e-fuels will continue to play a role in lower carbon intensity in heavier segments.

1 Current situation of the energy and transport sector

1.1 Road transport is the dominant European transport market for both passengers and freight

Based on statistical information presented in the 2018 Pocketbook Transport in Figures, published by the European Commission it can be concluded that the transport sector is segmented.

With respect to passenger transport in EU28, the large majority of passenger kilometres are driven by passenger cars (71%). Surprisingly, slightly more than 10% are travelled via intra-EU air travel. Busses and coaches are responsible of 8,1% and rail traffic is only nearly 7% of total passenger kilometres. See Figure 1. Total passenger kilometres amounted to 6,802 billion kilometres.

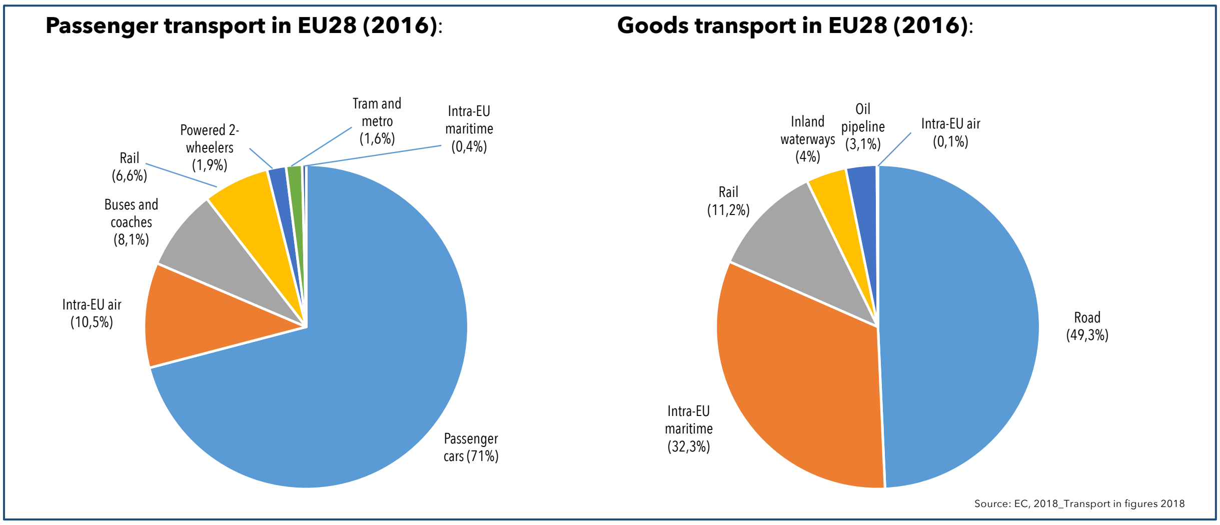

Figure 1. A segmented EU28 transport market (Source: EC, 2018, Pocketbook Transport in Figures 2018)

For freight transport road transport is also most important, responsible for early 50% of the total 3,661 billion tkm (2016). Intra-EU maritime transport (from one EU-port to another EU-port) is responsible for nearly one third of all freight tkm, and 11% of goods tkms are executed via rail. Both the road and intra-EU marine freight movements will for a long time to come still be dependent on energy-sense liquid fuels.

1.2 Greenhouse gas emissions are one on one related to fuel consumption

Road transport causes nearly 95% of all greenhouse gas emission in transport in the EU as can be seen from the next diagram.

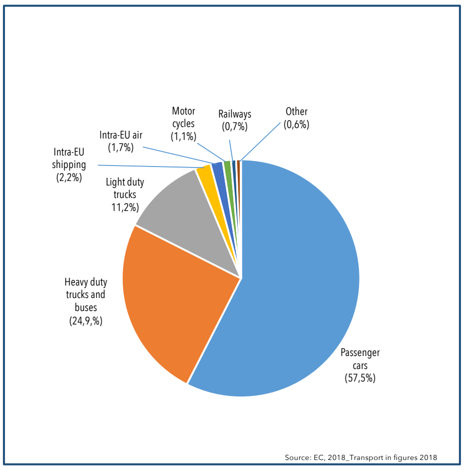

Figure 2 Greenhouse emissions in transport sector in EU (2016) Source, EC, 2018, Transport in figures

This is largely based on the fact that the transport sector is very oil dependent. The slide below from the International Energy Agency illustrates this clearly: worldwide more than 90% of the energy used in transport originates from oil. Even though this is data from 2012-report, the situation has not changed much. In 2016, the EU transport sector depended for 93,6% on oil.[4] The 2016 renewable energy shares in transport sector is approx. 5%, indicated in the Eurostat SHARES database[5].

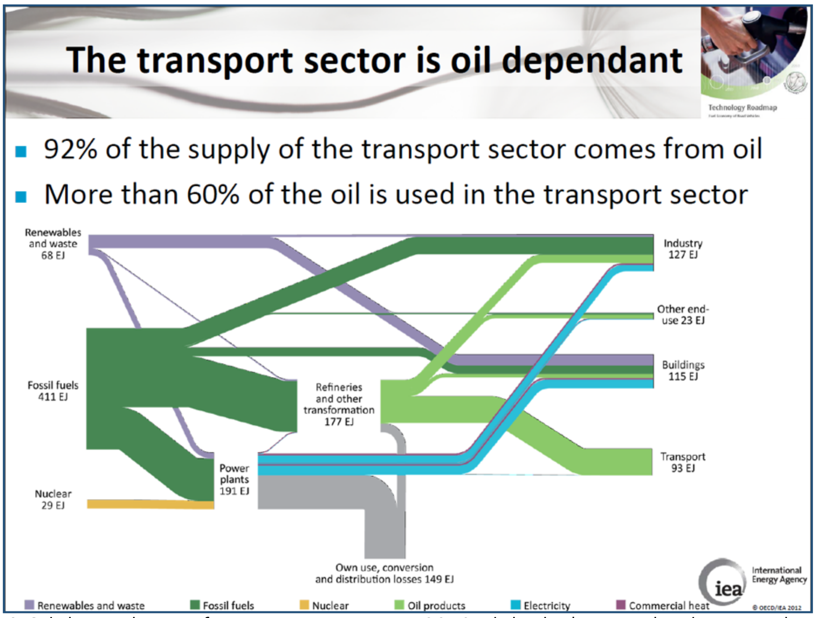

Figure 3 Oil dependence of transport sector, IEA, 2012, slide deck on Technology Roadmap on fuel Economy of Road Vehicles

1.3 Vehicle fleet development

Curbing the greenhouse gas emissions in transport by means of introduction of alternative vehicles will not be easy. The introduction pace of battery-electric and

[4] See https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Oil_and_petroleum_products_-_a_statistical_overview
[5] Eurostat SHARES 2016 results, downloaded via https://ec.europa.eu/eurostat/web/energy/data/shares

fuel-cell-electric vehicles is currently showing significant growth figures, but that is largely due to the fact that the absolute numbers are still very small, compared to the total annual new registrations and the total vehicle fleet.

Figures from the European Alternative Fuel Observatory illustrate the development of new alternative vehicles registrations, see Figure 4 for data from 2008-2018. The total Plug-in EV and the battery EV now total around 1 million passenger cars in the total fleet, representing about 1% of the total car fleet. From the second half of the previous decade to the first years of this decade much attention was focused on the introduction of CNG and in particular LPG vehicles as alternative to conventional diesel and gasoline vehicles. From the beginning of this decade the focus has shifted to the introduction of vehicles with an electricity drivetrain, both plug-in and battery electric vehicles. Figure 4 shows that on average, except for the year 2009, not more than 600 thousand alternative vehicles where registered. Given the total annual registrations in EU28 of approx. 12,5 million it must be concluded that up to now the share of alternative vehicles in total registrations sums up to max 5% of annual registrations. This implies that more than 95% of all passenger cars registered are still conventional ICE-vehicles, requiring liquid fuels. As these are about 20 years on average in the market, it will be necessary to provide fuels with reduced carbon intensity to these vehicles as to lower carbon emissions from these cars. Even in 2030, when according to EU targets at least 30% of registered passenger cars should be (partially) electric-based, the need for low carbon liquid fuels is evident.

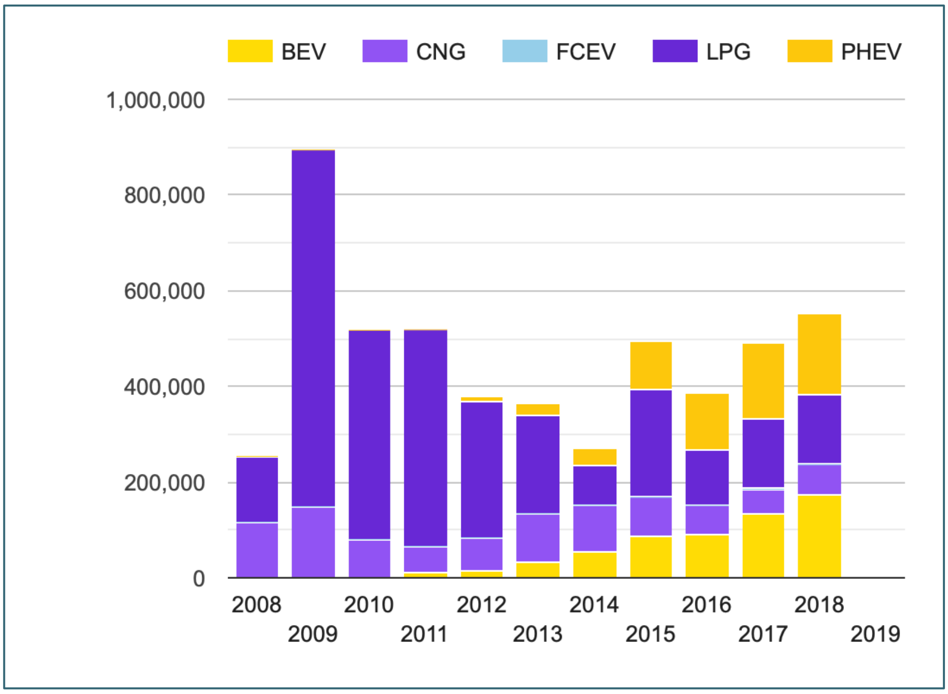

Figure 4 Annual registrations of alternative fuel vehicles[6]

The total passenger car fleet in Europe now sums up to 260 million passenger cars and 39 million commercial vehicles (2017-figures)[7], almost all based on internal combustion engines. In 1990 the passenger car fleet amounted a bit more than 160

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[6] Source: EAFO, https://www.eafo.eu/vehicles-and-fleet/m1#graphContainergraph_new_registrations__1

[7] See https://www.acea.be/statistics/article/size-distribution-of-the-vehicle-fleet

million cars. Trends from ACEA-data show that the passenger car fleet is still growing. While during the financial crisis the new registrations dropped, since 2014 registrations are on the rise again, as can be seen from Figure 5and reached about 15 million registrations in 2016.

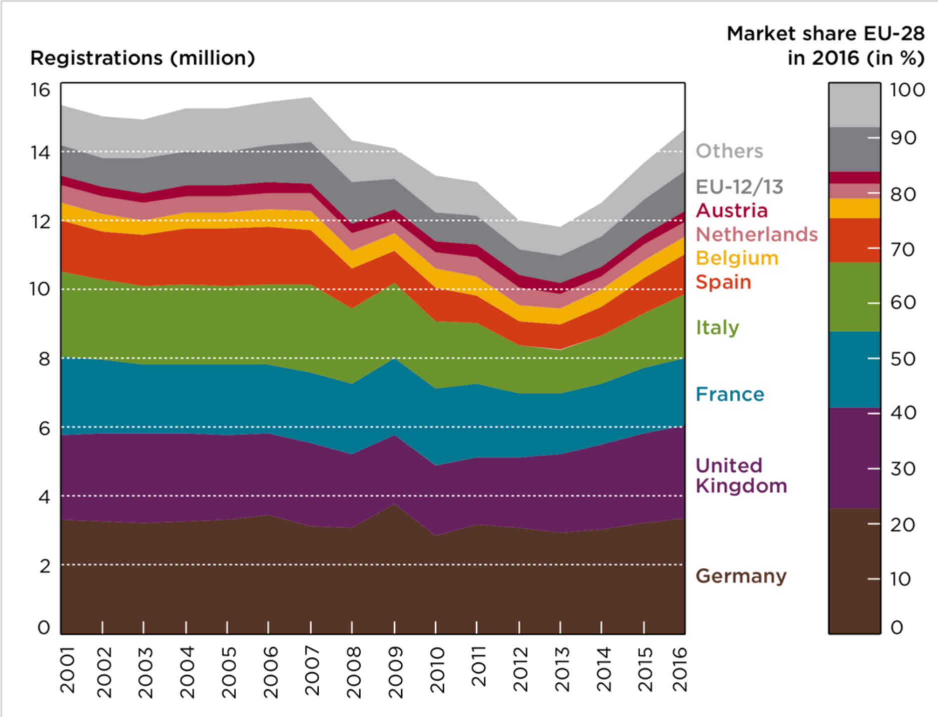


Figure 5 New Passenger car registrations in EU28, by member state[8]

This car fleet and new registrations makes it imperative that in order to significantly reduce greenhouse gas emissions in transport, renewable fuels need to become available for substituting high carbon intense fossil fuels, in addition to renewable energy fuelling electric vehicles entering the market. With European plans to achieve 30% EV passenger car sales in Europe by 2030 the market share of non-EV vehicles will remain dominant for quite some time. Certain EU Member States, like the Netherlands, have decided, or indicated to ban sales of ICE-vehicles by 2030 or some other dates.

But an analysis of the development of the total fleet shows that even in such case, the average renewal rate of cars causes a transition period for BEV-vehicles to achieve fleet dominance. This period will probably take more than 20 years. Figure 6 shows a calculation of how the introduction of battery-electric vehicles would impact the total vehicle fleet in the Netherlands. The actual numbers of the car fleet from 2009 up to 2016 have been taken into account (growing from 7,5 million to 8,2 million cars), assuming that in the next years the fleet will be unchanged. This means that cares leaving the fleet every year are replaced in the same number by new cars. Life time of cars is assumed 20 years. From 2016 onwards a gradual increased inflow of BEV's (blue) is assumed, reaching 100% by 2030, in line with the Dutch government plans to only allow electric vehicles being registered from that year onwards. It can be seen that combustion engine vehicles (in yellow) will be present in the fleet beyond 2040

[8] Source: ICCT, 2018, European Vehicle Market Statistics_Pocketbook_2017

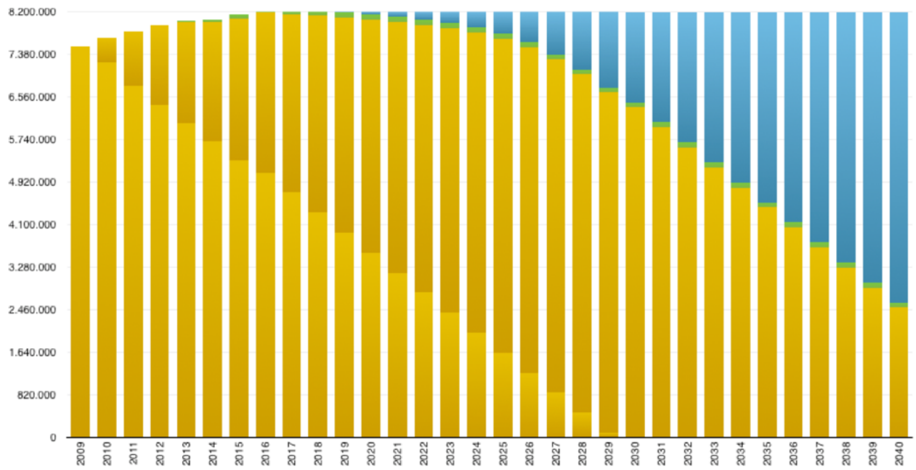


Figure 6 Development of passenger car fleet composition. yellow: ICE-vehicles, blue BEVs. Source: studio Gear Up analysis, 2017[9]

[9] See http://www.studiogearup.com/full-focus-on-electric-vehicles-is-not-enough-to-bring-down-carbon-emissions-in-the-netherlands/

2 Information on e-fuels

2.1 Collaborative role of renewable fuels and electric mobility

Various international organisations have indicated that both renewable fuels and electric mobility will be needed side by side to achieve lower carbon intensity in the transport sector.

IEA, the international energy agency report in its 2017 'Technology Roadmap – Delivering Sustainable Bioenergy' that next to the stark accelerating share of renewable electricity also the volume of renewable fuels, in casu in their report still only considering sustainable energy, would increase tenfold from 2005 up to 2060. Their analysis has a worldwide context. In Figure 7 this development is illustrated. IEA did not yet include in this report not yet the role of (renewable) power-to-liquid (PtL) or power-to-gas (PtG) fuels, but during a 2018 workshop in Brussels on low-carbon fuels it became clear that both biofuels and PtX are seen as renewable fuels, if based on renewable resources.

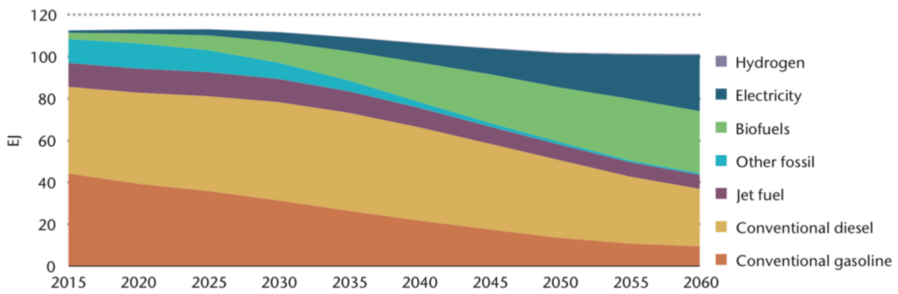


Figure 7 Final energy demand in transport under the IEA 2 degrees scenario (Source: IEA, 2017, Technology Roadmap – Delivering Sustainable Bioenergy)

IRENA, the International Renewable Energy Agency sketched also a 2050 scenario, the so-called RE-MAP2050 scenario in its 'Global Energy Transformation - a roadmap to 2050' report from 2018. Again, both electric mobility and renewable liquid fuels and gases (including H2) are dominating the energy carrier mix in the future. (see Figure 8).

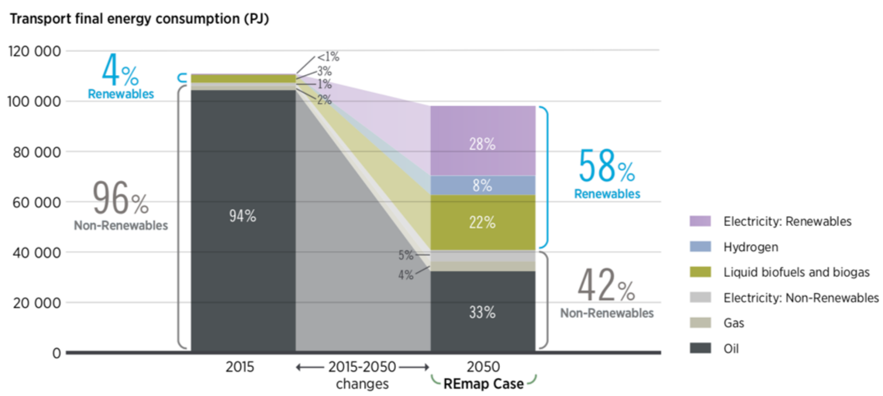


Figure 8 Transforming energy demand in the transport sector - A breakdown of final energy consumption in the transport sector, by source (PJ/yr) (Source: IRENA, 2018, Global Energy Transformation - a roadmap to 2050)

Various research institutes also have indicated in which transport segments the various energy carriers and fuels will in the end of the day play a dominant role. While this might become the reality in the coming decades it is god to know that in the current situation all transport segments are predominantly fuelled by liquid and to lower extent gaseous fuels and electric mobility, except in railways, is still in its earlier market introduction levels.

Mr. Tremel of Siemens showed in a presentation at the fuels of the Future Conference in Berlin - Jan 2018) how the various transport segments will be 'fuelled' (see Figure 9).

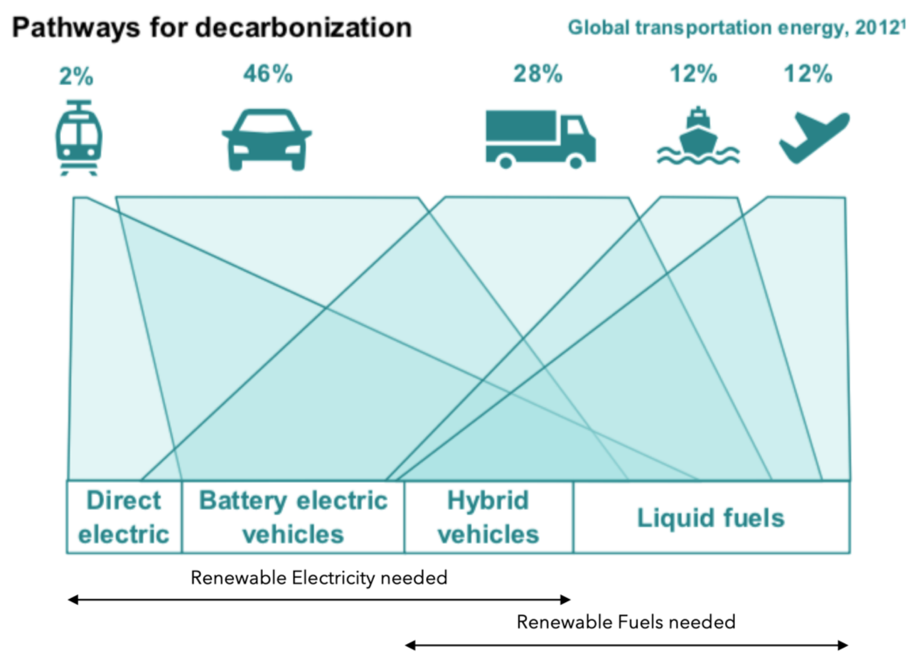


Figure 9 Pathways for decarbonisation (Source: Tremel, Siemens, 2018, Strombasierte Kraftstoffe, presentation at the 2018 Fuels of the Future Conference 2018

RICARDO executed in 2018 a scenario study for Concawe and Fuels Europe in which various scenarios where explored for the light duty vehicle market up to 2050 to identify the impacts on GHG-emissions and the costs associated of the various scenarios.[10] Next to a Business as Usual scenario three scenarios were explored:

- A high EV scenario, representing mass EV adoption to approx. 90% of the car parc in 2050
- A low carbon fuels scenario representing use of significant proportions of biofuels and e-fuels
- An alternative scenario representing use of more Plug-in EVs together with increased use of biofuels and e-fuels

[10] RICARDO, 2018, for Concawe, Impact Analysis of Mass EV Adoption and Low Carbon Intensity Fuels Scenarios

The key conclusion from this analysis is that in all scenario's the greenhouse gas emissions in transport in EU28 are reduced to less that 14% of the 2015 level and that the annual parc total cost to the end user are similar for the High EV and the Low Carbon fuel scenarios. (see Figure 10 and Figure 11)

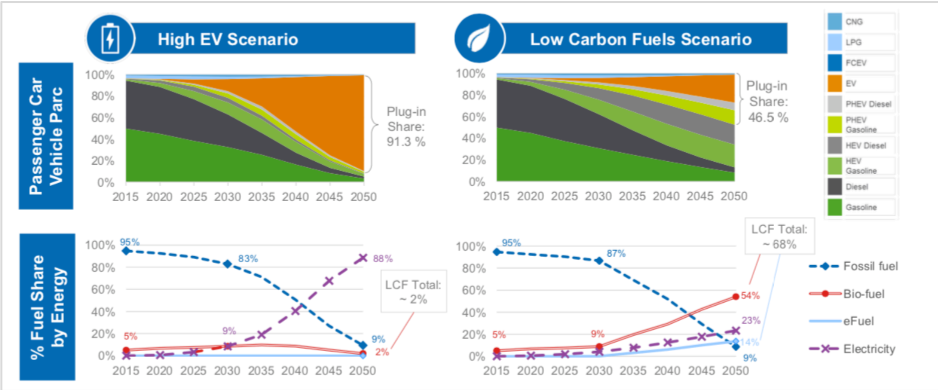


Figure 10 Comparison of the vehicle fleet and share of various energy carriers in the High EV and Low Carbon Fuels Scenario of RICARDO study. (Source: RICARDO, 2018, Impact Analysis of Mass EV adoption and Low Carbon Intensity Fuels Scenarios)

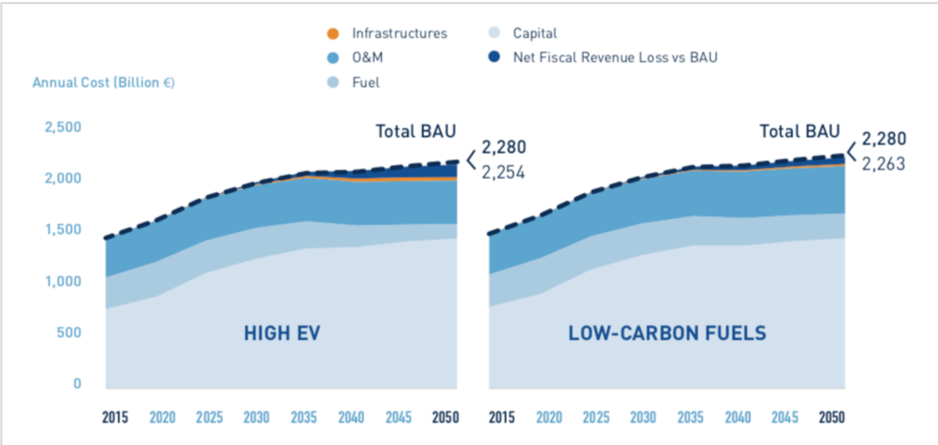


Figure 11 Total parc annual costs to end user for all light duty vehicles (Source: RICARDO, 2019, Key findings – a comparison of mass electric vehicles adoption and low-carbon intensity fuels scenarios.

A main lesson that can be drawn from this study is that that policy makers should be careful in making early technology choices, as the developments and progress in the various options available to achieve climate neutrality in transport are very dynamic. Policy makers should focus on the outcomes and create measures that enable market players to explore which approaches (i.e. technology options) are possible to achieve the desired outcomes. This enhances innovation in all fields and might lead to more cost-efficient solutions. This seems also a conclusion from a recent study by the German Energy Agency (dena), which concluded that technology openness brings lower total costs in achieving climate neutrality in transport than a preference focus on electrification only (see Figure 12).

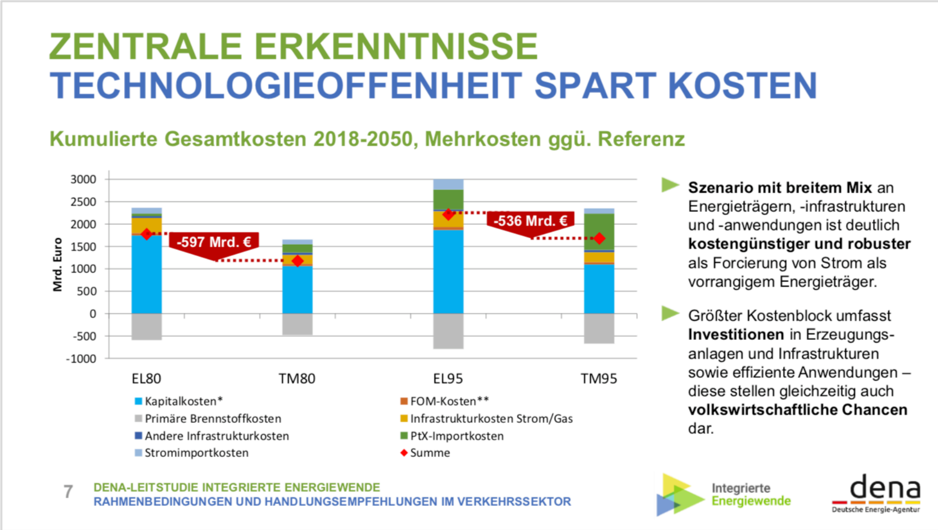


Figure 12 Technology-openness reduces costs for achieving climate neutrality in transport (Source: Kuhlmann, dena, 2019, Leitstudie Integrierte energiewende, Rahmenbedingungen und Handlungsempfehlungen für die Energiewende im Verkehr, presentation at the 2019 Fuels of the Future Conference

2.2 Production pathways for e-fuels

Prognos, in collaboration with DBFZ and Fraunhofer UMSICHT, and Frontier Economics, together with World energy Council/Weltenergierat Deutschland, published two reports[11] on the potentials, and international aspects of Power-to-X technologies. Information from these two reports will be presented here to provide more insights in the available production technologies and indications of the production costs of e-fuels.

For the production of power-to-liquid fuels, Prognos sees three conversion routes:

- Fischer-Tropsch (FT) synthesis
  FT is used to produce higher/longer-chain hydrocarbons using hydrogen (H_2) and carbon dioxide (CO_2) as input. The resulting hydrocarbons are drop-in synthetic gasoline or diesel substitutes. The hydrogen is to be produced from electricity, via electrolysis to view these FT-fuels as e-fuels. CO2 van either be captured directly from the air, or from CO2-rich waste streams, e.g. available at industrial production sites or as by product from bioethanol facilities.

- Methanol synthesis,
  Traditionally, methanol is produced from H2 and CO, with natural gas or coal as the main resource. When H2 is produced via renewable electricity and using CO2 from carbon rich sources or directly captured from the air, methanol can thus be produced from renewable electricity and CO2. Carbon Recycling international in Iceland is one of the first companies that have established such renewable methanol production

[11] Prognos, SBFZ, Fraunhofer UMSICHT, 2018, Status and perspectives of liquid energy sources in the energy transition.
Frontier Economics, World Energy Council/Weltenergierat Deutschland, International aspects of a power-to-X roadmap

- Polyoxymethylene Ether (OME) Synthesis,
  OME is known for its soot-mitigating impact when used as a diesel additive and it can burn without soot formation when used in pure form, as Prognos states in its report. This makes it a promising diesel substitute. To produce OME, methanol is the starting chemical component. As a result, due to the additional conversion steps that require energy, it has a lower overall energy efficiency. (around 38%)

For the production of power-to-gas fuels the main route seems to be[12]:

- Electrolysis from water to hydrogen,
  As mentioned in the pathways discussed above, hydrogen can be produced using renewable electricity via electrolysis. While in the above and next option the hydrogen is used as building block for hydrocarbons or methane, it also can be used directly. In that case specific infrastructure and logistics are needed to use the energy carrier in transport. In light duty vehicles and heavy-duty vehicles hydrogen is stored at 350 to 700 bars, to enable sufficient range for vehicles. In the vehicles it is converted to electricity via a fuel cell.
- Eventually followed by methanisation to produce methane.
  Audi is one of the first companies developing e-methane as a possible energy carrier for transport. In Werlte a power to gas demonstration facility is built in which H2 and CO2 are converted to e-methane (CH_4), to be used in gas engine-based vehicles.

In the figures below the various concepts are presented systematically.

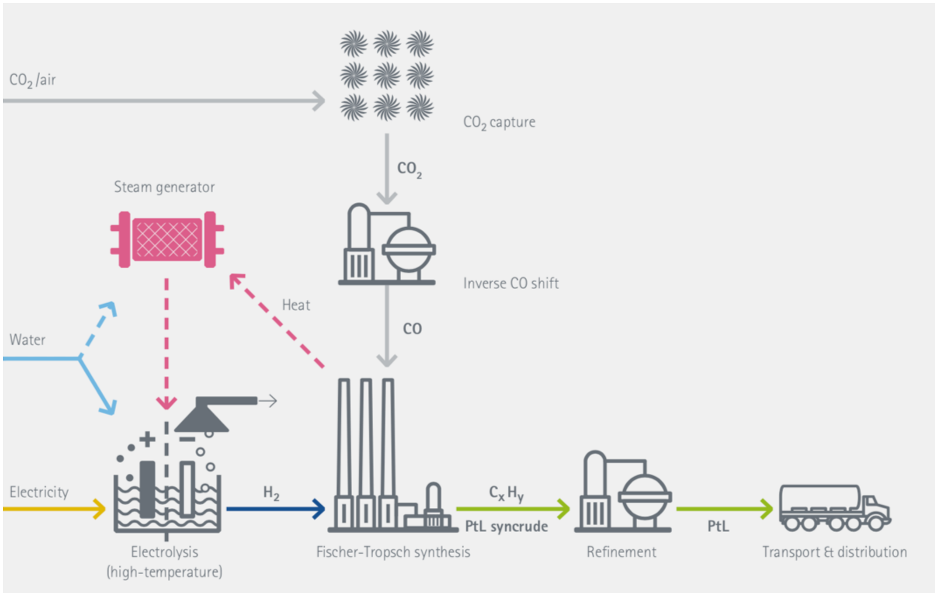


Figure 13 Schematic diagram of the Fischer-Tropsch process (Source Prognos 2018)

[12] See: https://www.audi.nl/nl/web/nl/modellen/layer/technologie/g-tron/power-to-gas-fabriek.html

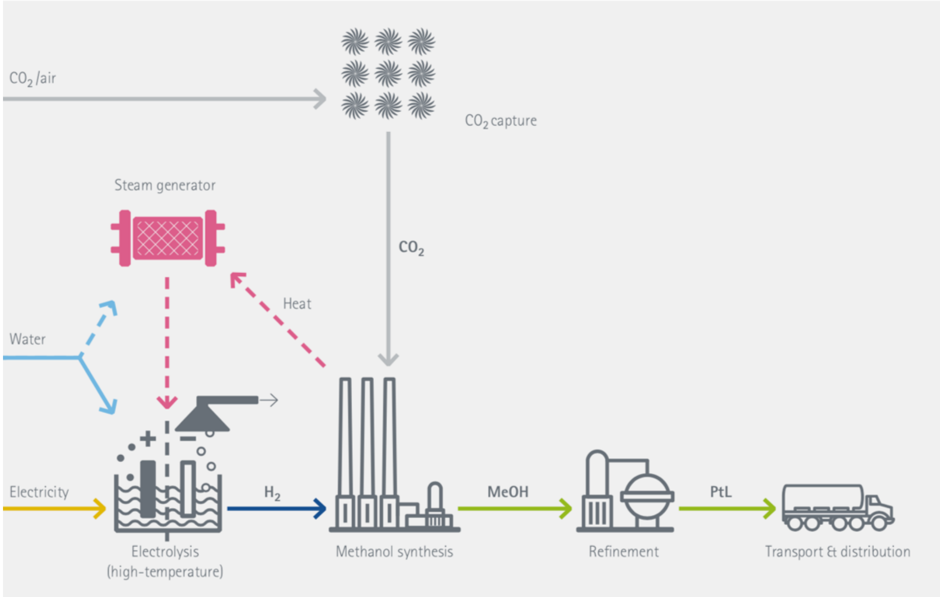


Figure 14 Schematic diagram of the methanol synthesis (Source Prognos 2018)

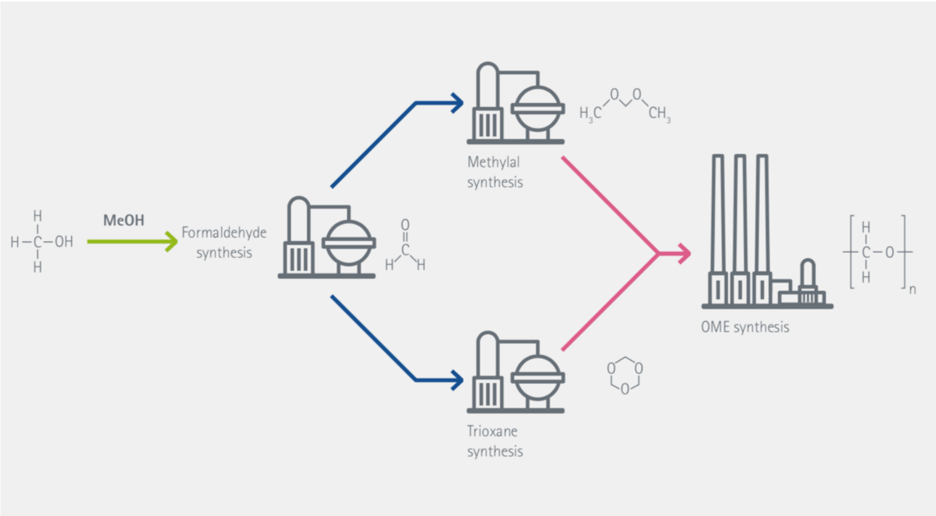


Figure 15 Schematic diagram of the polyoxymethylene ether synthesis (Source Prognos 2018)

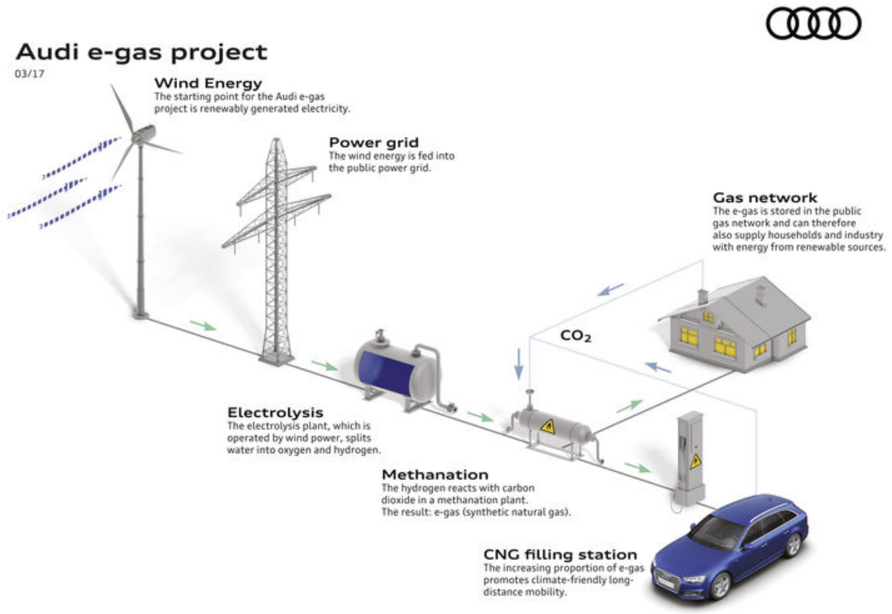


Figure 16 Schematic diagram of the power-to-gas process (Source Audi, 2019[13])

In summary, and with the addition of so new novel e-fuel options that are not included in this report, Frontier Economics has provided the following overview:

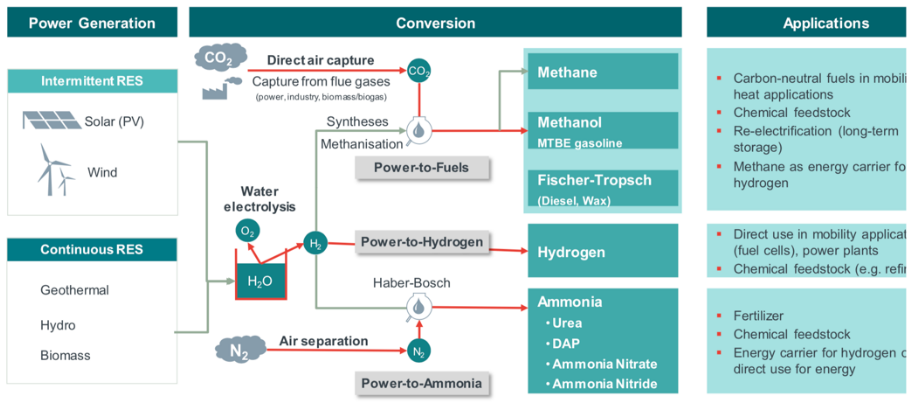


Figure 17 Power-to-X – conversion of renewable power into various forms of chemical energy carriers (Source Frontier Economics, WEC, 2018, International aspects of a power-to-X roadmap)

2.3 Energy efficiency for e-fuels

The conversion of electricity to liquid or gaseous fuels comes at the costs of efficiency, as can be seen from Figure 18. On average the conversion to electricity to hydrogen leads to 67% of the energy in the electricity available in the hydrogen. Due to the fact that the other e-fuel production processes built on hydrogen and are linked to the carbon-atoms, a process that requires energy, the overall energy efficiency is about 50%.

[13] Website visited 2019-03-10: https://www.audi-mediacenter.com/en/press-releases/new-audi-e-gas-offer-as-standard-80-percent-lower-co2-emissions-7353

Some organisations therefore argue that for that reason all focus and effort should go to EV's as these have a higher overall energy efficiency.

An important argument to continue the development of e-fuels, even with lower overall efficiencies is that volume wise spoken, the share of liquid and gaseous fuels currently and in the next decades to come will be substantial and need to be replaced by low-carbon alternatives. Renewable fuels, either biofuels or e-fuels have to deliver on this. The market inflow of electric mobility is dependent and the replacement rate of vehicles by EV-alternatives. The renewal rates, based on average life expectancy of 15-20 years for passenger cars, are too low to solely focus on electric mobility. Furthermore, e-fuels can reap the advantage of being able to be used in the existing fuels infrastructure.

In any case both the introduction of battery-electric vehicles and efuels will require the expansion of production capacity of renewable electricity. For EV's this electricity needs probably to be produced locally or at least nationally. E-fuels could be produced at location where abundant solar and/or wind energy is available, thus taking advantage of economies of scale and low production cost opportunities.

Both the Prognos study and the Frontier Economics report have sketched this international perspective of e-fuels production (see Figure 19) deployment of low carbon fuels in existing infrastructure is as important

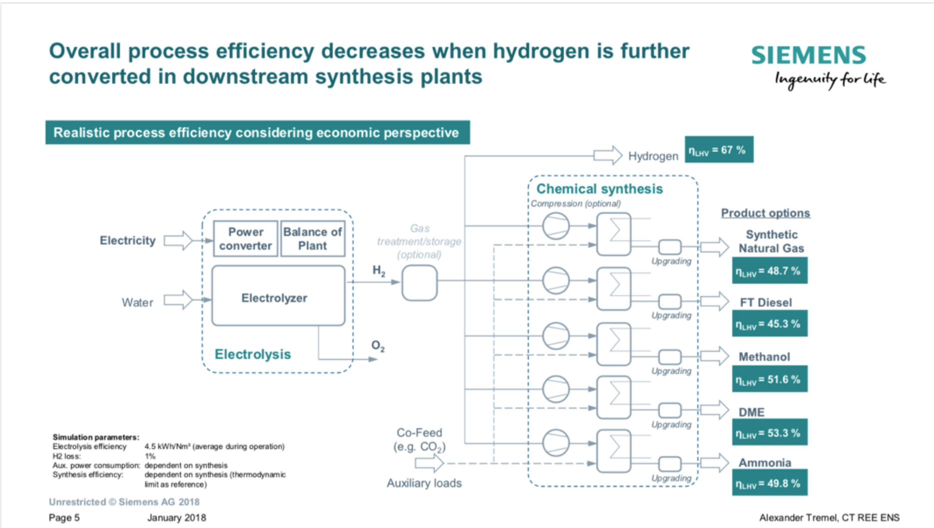
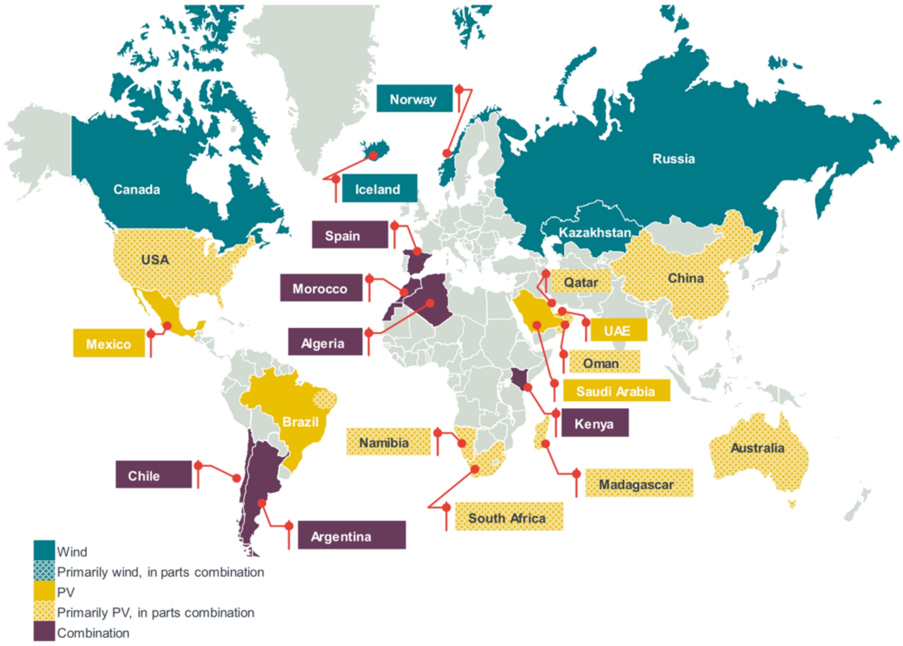


Figure 18 Energy efficiency of the various Power-to-X pathways (Source, Tremel, Siemens, 2018)



Source: Frontier Economics
Note: Illustrative presentation of the strongest RES potentials only; not an extensive list of all countries.

Figure 19 Snapshot of the variety and diversity of potential e-fuels producing countries (Source, Frontier Economics, 2018)

2.4 Insights on production costs for e-fuels

The 2018 Prognos report has examined two scenarios for the potential for e-fuels in the German context. Based on the German climate targets and ambition the report examined a scenario in which by 2050 an 80%-reduction of the 1990 GHG-emissions levels was to be achieved, and a scenario in which 95% reduction was realized in 2050. These two scenarios were compared against a reference scenario in which business and policy as usual was continued towards 2050.

Prognos estimated that the PtL requirements in 2050 could grow to 555 to 2,000 PJ in the 95%-reduction scenario, equalling 44% of the primary energy consumption currently covered by mineral oil in Germany. In addition to that also the Power-to-Gas share would increase substantially too. As can be seen from Figure 20. It must be noted here, that in the Prognos study a rather limited share of battery-electric vehicles are foreseen in 2050. They estimate: "*we are assuming 14 million electrically powered cars, 5 million of which are plug-in hybrids. This means that in 2050, 20 % of cars will be powered purely electrically*" (Prognos 2018, page 34). In case the numbers will be higher (target for 2030 is 6 million vehicles), than the requirements for e-fuels will be lower than assessed in the Prognos report.

	2000	2030	2040	2050
Scenario PtX 80				
PtDiesel	8	154	760	765
PtG	11	275	945	993
PtH_2	0	1	15	39
PtHEL	4	57	231	237
PtKerosine	2	45	271	329
PtPetrol	4	69	361	350
Total	**29**	**602**	**2,584**	**2,712**
Thereof share of PtL	**61 %**	**54 %**	**63 %**	**62 %**
Scenario PtX 95				
PtDiesel	8	171	914	910
PtG	11	318	1,146	1,528
PtH_2	0	1	17	41
PtHEL	4	63	277	283
PtKerosine	2	51	331	397
PtPetrol	4	79	445	427
Total	**29**	**683**	**3,130**	**3,586**
Thereof share of PtL	**61 %**	**53 %**	**63 %**	**56 %**

Figure 20 Use of synthetic energy sources, 2020-2050 (Source, Prognos, 2018)

Prognos estimates that in 2050, the $Euro_{2015}$ costs production costs of greenhouse gas neutral efuels (based on Fischer-Tropsch production pathway) could be between 0,5 and 0,9 $€_{2015}$/l, at 2% interest rate and 0,7 and 1,3 $€_{2015}$/l, at 7% interest rate. These low prices are achieved at locations optimised for low cost production, and thus not necessarily based in Germany. The following figure indicates the ranges for low-level production and higher cost circumstances.

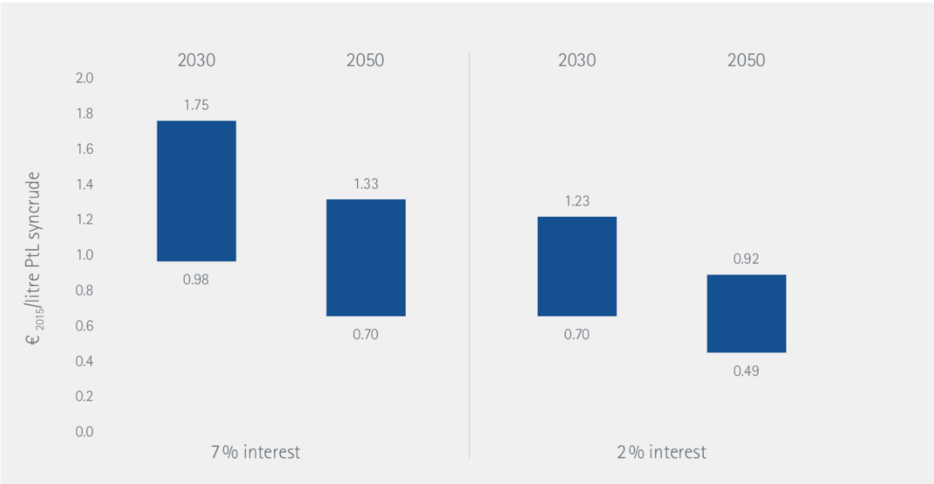


Figure 21 Range of production cost of e-fuels in 2030 and 2050 (Source, Prognos, 2018)

3 About balancing the grid and energy storage

Europe is well on track to achieving its renewable energy target of 20% by 2020, as can be seen from the graph below.

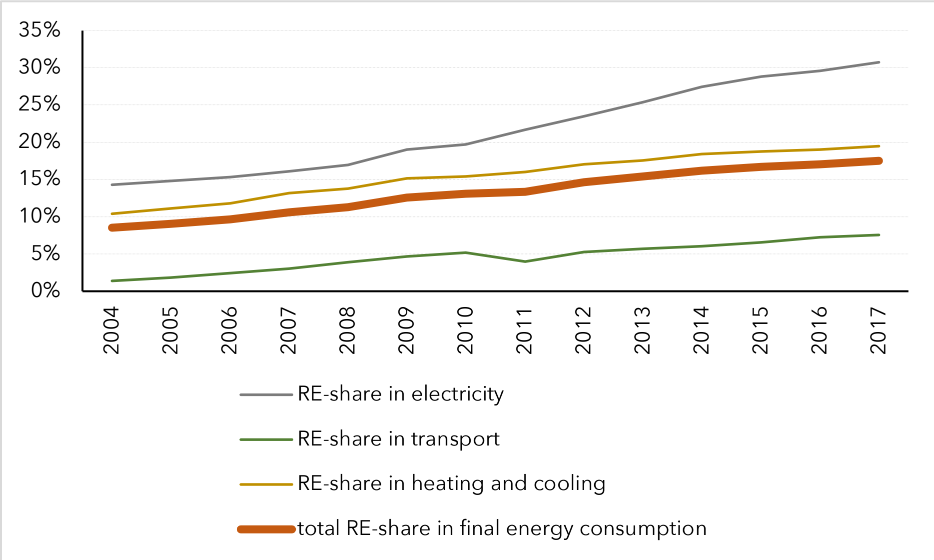


Figure 22 Renewable energy shares in transport, heating and cooling and the electricity sector in the period 2004-2017. Source: Eurostat 2019, SHARES summary results 2017

In the new Renewable Energy Directive, the target for overall share of energy from renewable sources in final energy consumption should further grow to 32%.

The share of renewables is largest in the electricity generation sector. In 2017 renewable sources where responsible for 30,75% of all electricity generated in EU28[14]. With an increasing share of renewable energy, and especially with the growth in solar and wind energy, the amount of variable electricity in the electricity grid will grow. The two graphs below show how in absolute terms the amount of renewable energy in electricity generation developed and how much of that was variable renewable energy (solar and wind energy) and non-variable renewable energy, being more stable and controllable (hydropower, biomass and other renewables). The total share of electricity from renewable sources in 2017 was as a result 14,2% (46,2% share of variable of all renewable electricity, with 30,75% share of renewable electricity in total electricity.

[14] There is a wide variation among the EU member states. Austria reached 72% in 2017, Sweden 66% and Denmark 60%, to mention a few. Germany, as the largest in electricity production, reached 34%

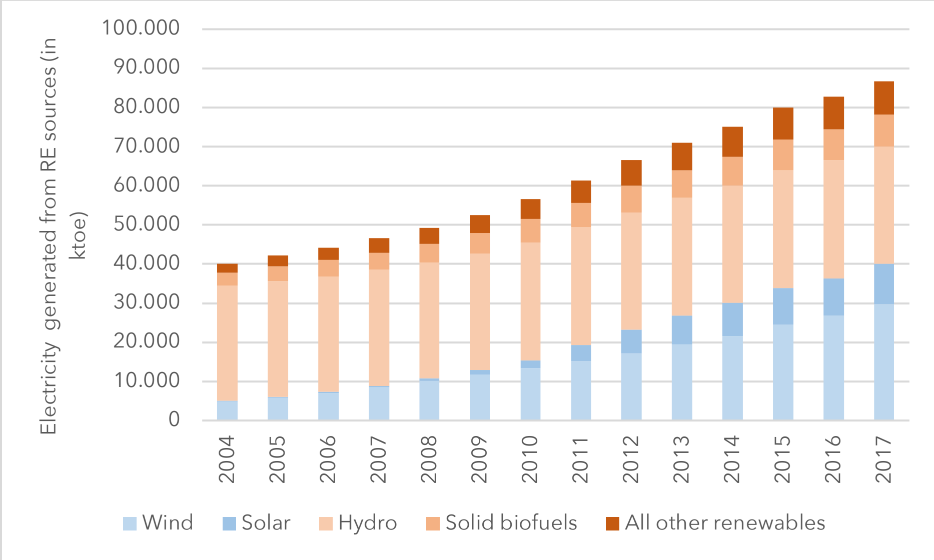


Figure 23 Development of electricity generation from renewable sources. Variable renewables in blue, non-variables in orange, 2004-2017. Graph by sGU, data from Eurostat 2019, SHARES summary results 2017

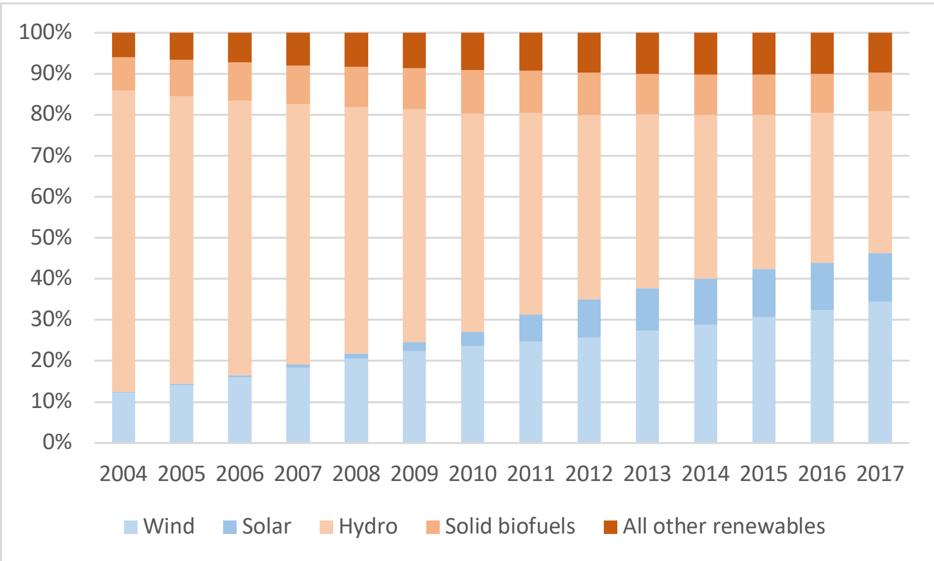


Figure 24 relative share of variable and non-variable renewable energy sources in electricity generated from renewable, 2004-2017. Graph by sGU, data from: Eurostat 2019, SHARES summary results 2017

It can be expected that this share will further increase as growth of renewable electricity is largely based on the expansion of the development of wind energy and solar energy.

This already today creates situations (especially on stormy, while sunny, days) that more electricity is generated than demand is at that time, or that the electricity is generated decentral and the central grid system is hardly capable of transmitting the produced amount of electricity. For that reason, currently already moments occur in which electricity has a negative price. The next two graphs present information from

Germany for 2017 and 2018 showing peaks with negative prices, due to abundancy of variable renewable electricity produced.[15] In Germany the share of renewables was 36,1% in 2017 and 38,2% in 2018. It is expected that this will rise to approx. 65% in 2030.

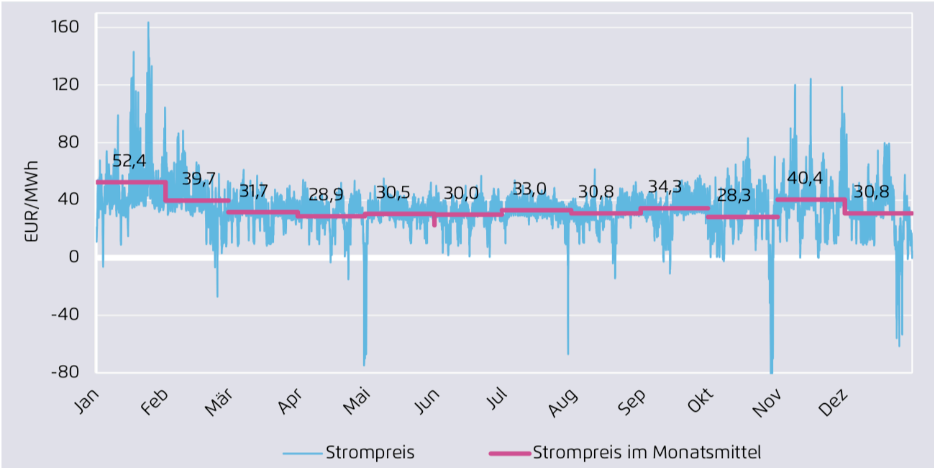


Figure 25 Hourly and monthly prices for electricity generated in Germany in 2017. (Source, Agora Energiewende, 2018, Die Energiewende im Stromsektor: Stand der Dinge 2017)

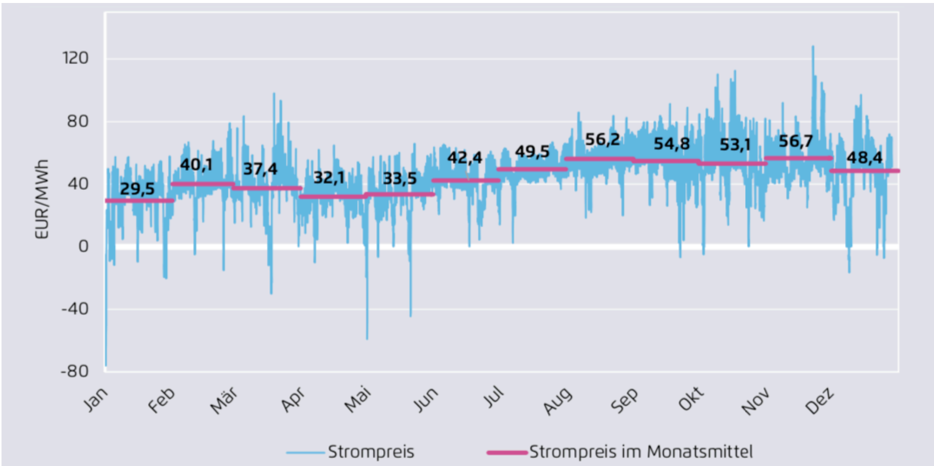


Figure 26 Hourly and monthly prices for electricity generated in Germany in 2018. (Source, Agora Energiewende, 2019, Die Energiewende im Stromsektor: Stand der Dinge 2018)

This imbalance of the grid, and also the current still limited capacity of electricity storage (see Figure 27) provides opportunities for storing the generated electricity in liquid and gaseous energy carriers.

[15] At the same time, a learning effect is noticed as well as there are less and lower peaks in 2018; market players take measures to prevent negative prices as much as possible.

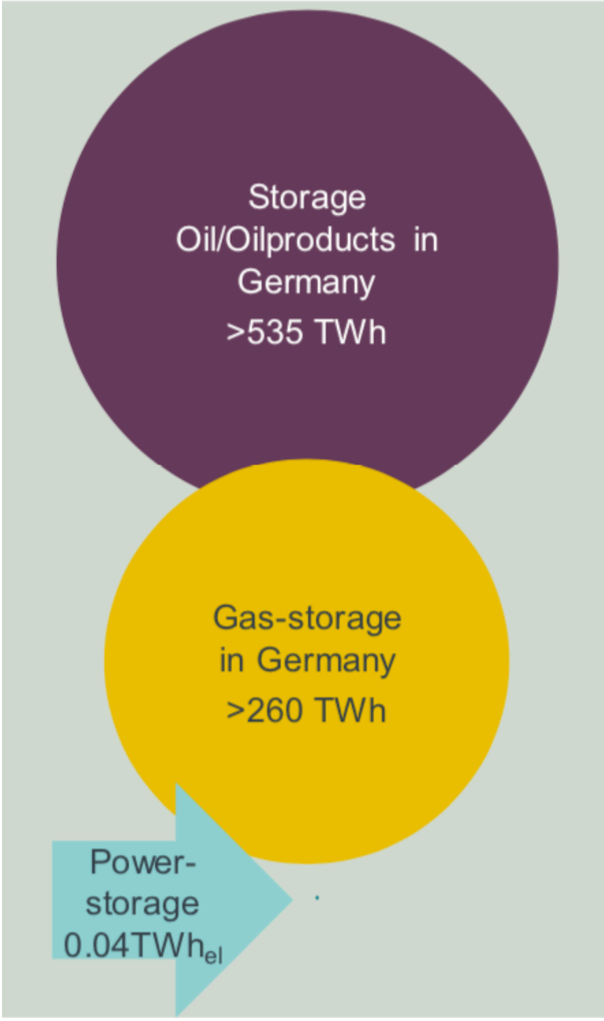


Figure 27 Current existing energy storage capacity in the liquid, gaseous and electricity infrastructure in Germany. (Source: Frontier Economics, 2018, Synthetic energy Sources - perspectives for the German Economy and international trade)

The International Energy Agency (IEA) provided a clear overview of the various energy storage options available, based on the time period storage is needed. In the power generation sector, sometimes storage is needed at microsecond level to keep demand and supply in balance, requiring specific technology, whereas for longer term storage (weeks, seasons) other techniques are required in which the electricity is converted to e.g. chemically bound energy is liquid or gaseous energy carriers. The overview was provided in a report on a hydrogen roadmap, published in 2015. Where hydrogen is mentioned in the diagram, one could easily read electro-fuels as a broader terminology for liquid and gaseous energy carriers.

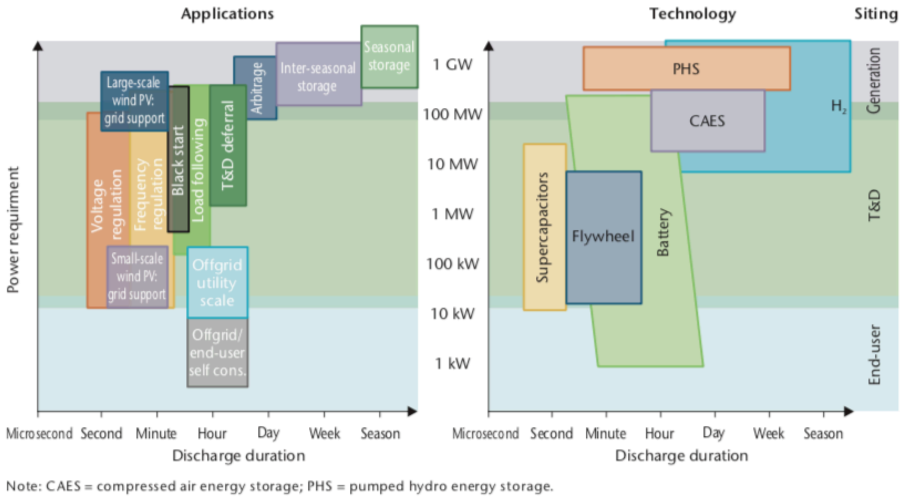


Figure 28 Electricity storage applications and technologies. (Source, IEA, 2015, Technology Roadmap Hydrogen and Fuel Cells)

In conclusion it can be stated that e-fuels can contribute to balancing the grid due to its energy storage capacity in liquid and/or gaseous form, thereby enabling the use of these e-fuels in the existing infrastructure and vehicles.

Annex 1: The impact of the 2015 Paris Climate Agreement

In 2015 at the 21st UNFCCC Conference of the Parties (COP) a historical agreement[16] was signed. The relevant section of Article 2 of the Agreement is copied below:

This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

a. Holding the increase in the global average temperature to well below 2 °C above pre- industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

b. Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and

c. Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

While in Europe various roadmaps where published in the years before the Paris Agreement on achieving a low-carbon economy and setting out strategies for energy and climate, end of 2018 the European Commission once more emphasised the transition towards a low-carbon future. The Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050.

"The strategy shows how Europe can lead the way to climate neutrality by investing into realistic technological solutions, empowering citizens, and aligning action in key areas such as industrial policy, finance, or research – while ensuring social fairness for a just transition.

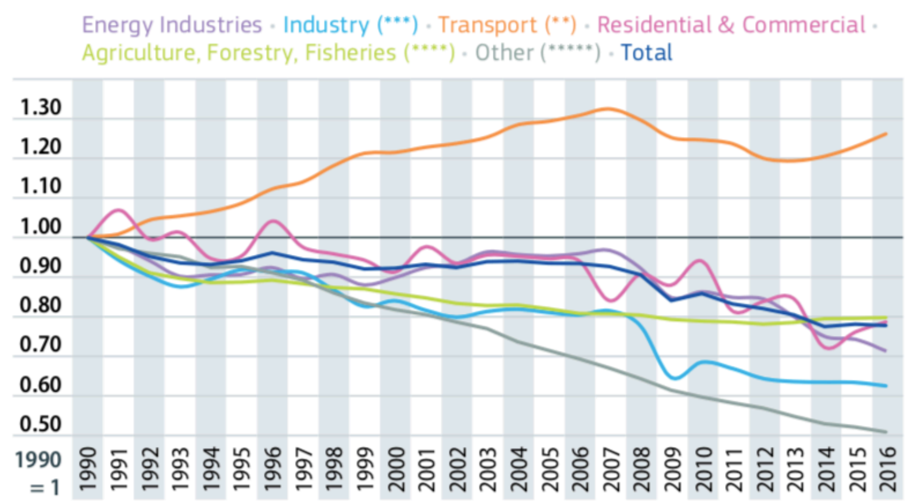
Following the invitations by the European Parliament and the European Council, the Commission's vision for a climate-neutral future covers nearly all EU policies and is in line with the Paris Agreement objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C."[17]

The EU28 as a whole is on track with respect to achieving the 2020 targets on greenhouse gas saving (-20% in 2020, compared to 1990). In 2013, 14% this target was already achieved.[18]

Interesting however is that the development of the carbon emissions in the transport sector are increasing and still above 1990-level, unlike the other economic sectors

[16] https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf
[17] https://ec.europa.eu/clima/policies/strategies/2050_en
[18] https://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_climate_change_and_energy

(energy generation, industry, build environment and the agricultural sector). This can be seen in Figure 29. Total 2016 greenhouse gas emissions in the EU are 21% below 1990 level, whereas emissions in transport are still 27% higher and since 2014 onwards again increasing.



Notes: (*) Excluding LULUCF (Land Use, Land – Use Change and Forestry) emissions and international maritime, including international aviation and indirect CO_2.
(**) Excluding international maritime (international traffic departing from the EU), including international aviation.
(***) Emissions from Manufacturing and Construction, Industrial Processes and Product Use.
(****) Emissions from Fuel Combustion and other Emissions from Agriculture.
(*****) Emissions from Fuel Combustion in Other (Not elsewhere specified), Fugitive Emissions from Fuels, Waste, Indirect CO_2 and Other.

Figure 29. Development of greenhouse gas emissions in the EU (Source: EC, 2018, Pocketbook Transport in Figures 2018)

This demonstrates the challenge to curb the emission trends in the European transport sector. Already in 2011, prior to the Paris Agreement, the European Commission published a 'Roadmap to a resource efficient Europe'[19] in which an ambition of 60% lower GHG savings in transport in 2050 compared to 1990 was described. Options are also in more detail described in the Transport White Paper that the commission also published in 2011[20]. Many countries, like e.g. the Netherlands and Germany have announced national translations of such ambitions, taking into account the increased implications from the Paris Agreement. The Netherlands aims at achieving a maximum CO2-emission level of 25 Mton CO2[21] in 2030 that lies 22% below 1990 level (and 38% below the highest CO2-emissions level, realised in 2006.[22] Germany wants to achieve by 2030 a 40-42% reduction of CO2-emissions compared to 1990.[23]

[19] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0571
[20] https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en
[21] This number is on a tank-to-wheel basis
[22] Based on non-published information in the process of Climate Agreement negotiations. Data available via Statistics Netherlands: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70946ned/table?dl=10757
[23] https://www.bmu.de/themen/klima-energie/klimaschutz/nationale-klimapolitik/klimaschutzplan-2050/#c8420

As will be discussed later, the introduction of battery-fuelled electric cars is part of the option package to decrease the carbon intensity of energy carriers used in the transport sector. Various countries have announced to shift to sales of electric-only passenger cars by 2030 or another later date and in the meantime stimulate the market uptake of such vehicles.

The market introduction rate of these vehicles might not go quickly enough, given the renewal rate of the European car fleet to provide immediately significant carbon emission reduction.[24].

The remaining carbon budget to stay well below 2°C is expected to be depleted within 18 years, given the current emission level of approx. 40 Gt C per year. Prof. dr. Willner of HAW Hamburg illustrated this in his 2018 presentation at the Fuels of the Future conference in Berlin[25]:

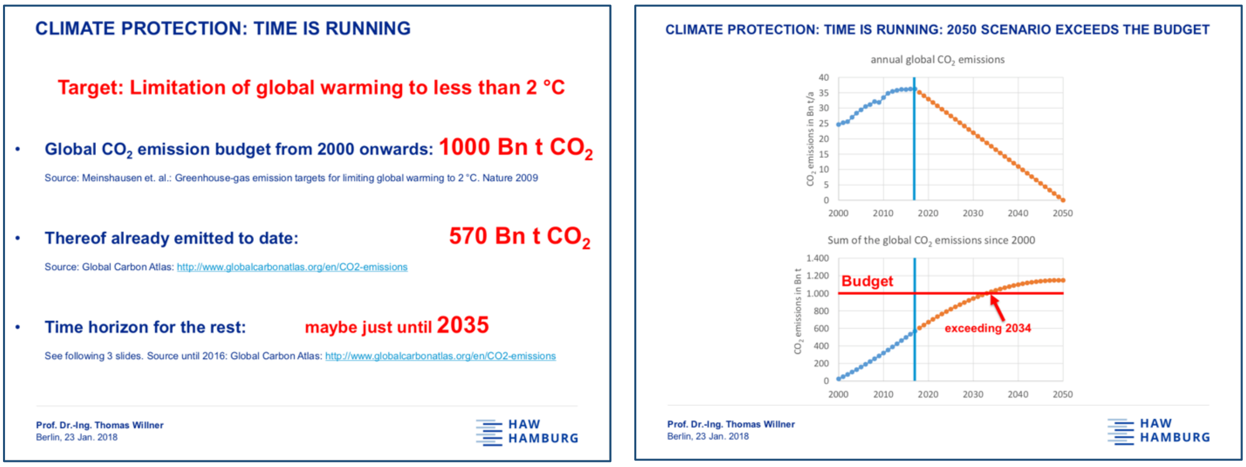


Figure 30. concept of Carbon Budget depletion explained (Source: Willner, 2018)

Assuming a linear decrease of the annual CO2-emissions to reach zero in 2050, the carbon budget would be exceeded by 2034. Willner showed that in case of a linear decrease of the carbon emissions, the zero-level should be reached already at 2041. The main message that could be drawn from his analysis is that the carbon emissions should decrease at a quicker pace to secure achieving zero emissions at 2050 and staying below the 'Paris'-levels. This calls for deploying options that are currently able to bring carbon emission reduction to the table, making use of the existing infrastructure and vehicle fleet, as an inseparable part of a strategy that aims at introducing electric mobility to the market.

[24] see information in e.g. https://www.theicct.org/sites/default/files/publications/ICCT_Pocketbook_2017_Web.pdf, https://www.eafo.eu/vehicles-and-fleet/m1, https://www.acea.be/statistics/tag/category/report-vehicles-in-use

[25] Willner, 2018, Importance of liquid alternative fuels for climate protection – a ProcessNet position paper, presented at Fuels of the Future, 22 January 2018, Berlin, Germany