MOTOR & UMWELT 2017
ENGINE & ENVIRONMENT 2017

Zero CO_2 Antriebe im Vergleich zwischen tank-to-wheel und well-to-wheel Bilanz

Zero CO_2 Powertrains in Comparison of Tank-to-Wheel and Well-to-Wheel Balance

Christof Schernus

Dr. Thorsten Schnorbus
FEV Europe GmbH

Kurzfassung

Während in der Öffentlichkeit der batterieelektrische Antrieb verbreitet als der einzige Weg zur CO_2-freien Mobilität gesehen wird, bieten regenerative Kraftstoffe ein deutlich unterschätztes Potenzial, eine ganzheitliche Senkung des CO_2-Ausstoßes zu erreichen. Dies gilt sowohl für ihre Nutzung in Brennstoffzellen als auch in Verbrennungsmotoren. Wesentlich für die Senkung der CO_2-Emission in der Bilanz von der Quelle zum Rad (well-to-wheel) ist die Nutzung regenerativer Energie für den Antrieb, was auch bei reinen Elektrofahrzeugen aufgrund des Energiemixes derzeit nicht gewährleistet ist.

Dieser Beitrag berücksichtigt im Vergleich der Antriebskonzepte die CO_2 Bilanzen einerseits bezogen auf den Energiespeicher des Fahrzeugs (tank-to-wheel) und stellt diese der Bilanz bezogen auf die Quelle der gespeicherten Energie gegenüber. Dabei spielen Herstellung und Verteilung von Energieträgern eine wichtige Rolle. Zur Vereinfachung beschränken die Autoren den Vergleich der Antriebskonzepte auf einen Personenkraftwagen der Mittelklasse.

Abstract

Whilst the public audience often recognises only battery-electric vehicles (BEV) as the only pathway to CO_2-free mobility, the potential of regenerative fuels for achieving an overall decrease of CO_2 emissions is significantly underestimated. This holds true for their use in fuel cells as well as in internal combustion engines. When it comes to reducing the well-to-wheel based CO_2 emission, it is the usage of regenerative energy for propulsion that matters. With the mix of primary energy used for electricity in the grid, also BEVs do not achieve a zero carbon footprint, yet.

The powertrain concept analysis in this article considers on the one hand the CO_2 balance relative to the in-vehicle energy storage (tank-to-wheel, short: T2W). This is compared to the balance relative to the sourcing of that stored energy (well-to-wheel, short: W2W). Production and distribution of energy carriers play an important role in this context. For simplicity, the powertrain comparison is limited to midsize passenger cars.

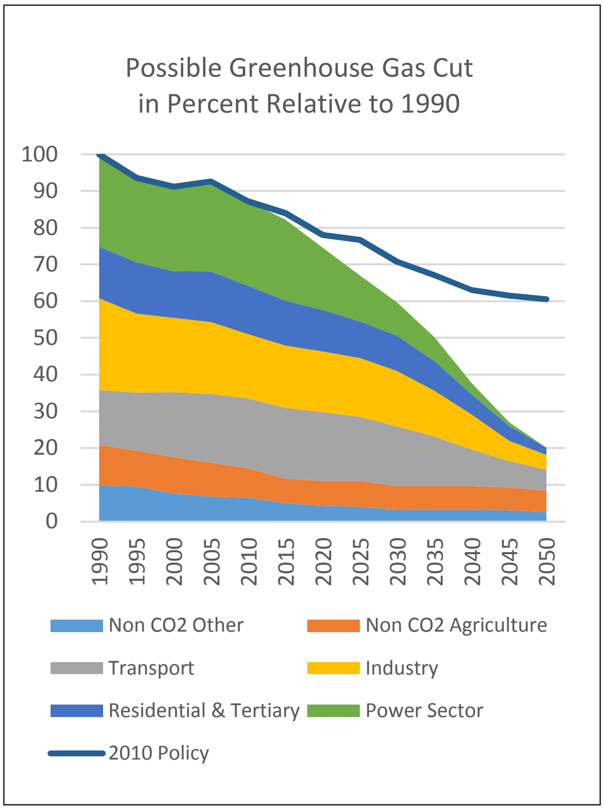

Figure 1: 80% cut in GHG emissions in the EU (100%=1990)[1]

Introduction

The need to reduce anthropogenic greenhouse gas (GHG) emissions to decelerate global warming and its overall detrimental effects is accepted by most governments and societies. In suite to the 2015 Paris Agreement, European policy makers have set the ambitious economy-wide target to cut at least 40% of the GHG emissions by the year 2030 versus 1990 and 80% compared to 1990 levels by 2050 (European Commission, 2017). The transport sector shall contribute to this by reducing 60% of its CO_2 emissions.

The European Commission expects a very high share of renewable energy sources (RES) in electricity consumption of 97% in 2050 (European Union, 2011). Cutting GHG emissions with the focus on CO_2 means replacing fossil primary energy carriers preferably by renewable energies like wind and solar power. As these power sources undergo periodical and random daily and seasonal changes, they may introduce instability into the power supply. Due to limited raw materials supply, battery power plants cannot be the only storage of temporary excess regenerative energy to bridge periods of lacking sunlight and wind. Also, a further increase of pumped-storage hydropower plant capacity suffers from lacking public acceptance as well as detrimental ecologic impact. Therefore, governments consider an integrated energy system approach, in which synthetic chemical energy carriers come into focus that would be compatible with present storages, like natural gas caverns or liquid fuel storage tanks. Such power-to-X fuels can be blended with other fuels from regenerative sources like landfills, biomass hydrolysis or fermentation.

60% less CO_2 from transport in 2050

As mentioned above, the European Commission assigns a 60% reduction of CO_2 emissions to the transport sector. If this considers only a T2W balance, the choice of mobile energy storages is limited to electric batteries and hydrogen tanks. Vehicle concepts would be restricted to BEV and FCEV (or ICE running on hydrogen), then.

Extending the scope of CO_2 emissions to a W2W balance, however, brings regenerative hydrocarbon fuels into consideration, which allow using internal combustion engines (ICE) for energy conversion in future electrified powertrain concepts.

The general advantage in particular of combustible fuels that are liquid at standard conditions is easier transportation and refilling. Moreover, they provide a much higher energy density than batteries. Even when considering inferior efficiency of internal combustion engines, the range per unit mass or unit volume of energy storage cannot be beaten by batteries. On the other hand, a heavy battery in the very bottom of the car can lower the centre of gravity significantly and enable a great handling of the car. Its major advantage over combustible fuels is in any case the ability to store energy regenerated during deceleration.

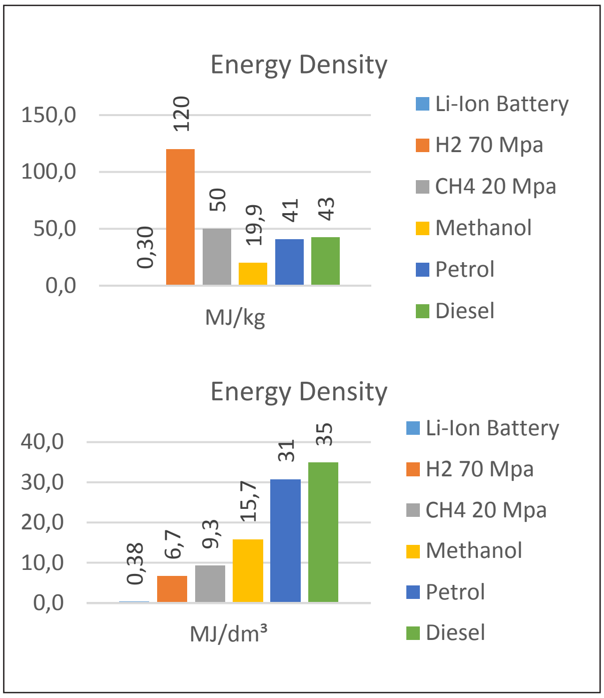

Figure 2: Energy density per mass (upper) and volume (lower diagram) of Energy Carriers for Vehicles

The following overview of powertrain concepts will deal with BEV and hybrid vehicle concepts.

BEV

The ERTRAC Electrification Roadmap expects a reduction of BEV energy consumption by 2030 to 115-120 Wh/km from 140 Wh/km in 2016[2]. Contributing factors will be a progress of dedicated EV design with lightweight materials, an increase of battery energy density from 160 Wh/kg today to above 330 to 500 Wh/kg in 2030 allowing for less vehicle weight, and a stronger penetration of ADAS and autonomous driving functions saving energy during drive.

While the T2W CO_2 emission of BEVs obviously is zero, their W2W footprint depends on the primary energy mix. From 1990 to 2014, the EU average CO_2 emission of electric power production dropped from 431 g/kWh to 275.9 g/kWh with a strong variation around the EU 28 countries' average (European Environment Agency, 2016) depending on the substitution of fossil primary energy by renewable and nuclear energy.

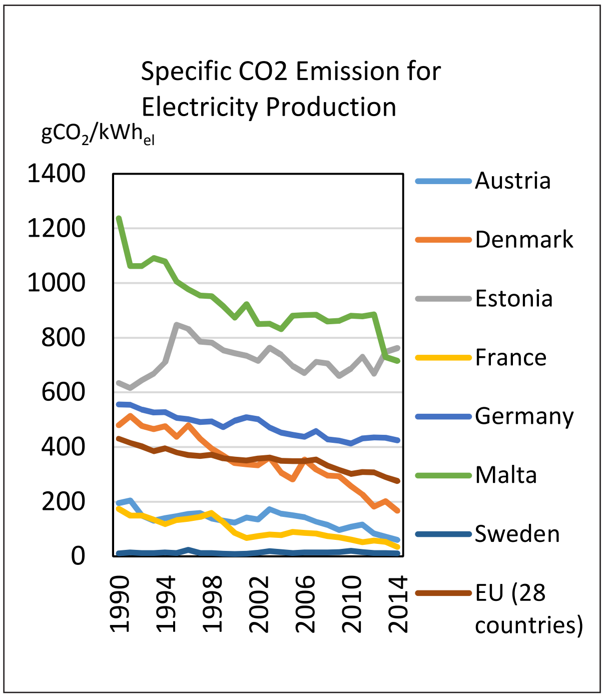

Figure 3: CO_2 emission of the electric power generation in Europe and some example member states, data from (European Environment Agency, 2016)

Assuming the EU average CO_2 emission of electric power production will continue dropping to 180 g/kWh by 2030[3], still the W2W carbon footprint of a BEV will range from an NEDC average of 23-24 g CO_2/km to a WLTC average of 37-39 g CO_2/km in 2030. Continued decarbonisation of the power supply sector, changing user habits with a continued trend to urbanisation may contribute to in-operation CO_2 emissions of BEVs near zero in 2050.

When it comes to assessing lifecycle GHG emissions, the production of the entire vehicle has to be considered.

Here, the battery plays an important role, According to (ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, 2016), the GHG emitted during battery production currently amounts to a CO_2 equivalent of approximately 13 kg per 1 kWh of battery capacity. This GHG allocation to transport could be reduced to 75%, further usage of batteries in a "second life" e.g. in stationary applications is considered, after their useful lifetime in transport has ended because of degrading capacity

HEV

Hybrid Electric Vehicles are known as vehicles combining typically an internal combustion engines with electric machinery for electricity generation and propulsion. Depending on the degree of ICE-based powertrain electrification, micro-, mild and full hybrids are distinguished. They differ mainly in size of the electric machine. Also the position(s) of the electric machine(s) are used as a criterion for characterisation.

The main idea of hybridisation is to enable regenerative breaking, i.e. recuperating the kinetic energy during deceleration and providing it for driving or acceleration thereafter. Such hybridisation has already been demonstrated in mechanical KERS systems using flywheels, like in Formula 1 from 2009 - 2014, or with hydraulic or pneumatic pressure tanks. In an HEV, the energy is stored after conversion into electric power, which is then charged in a battery or capacitor. Recent developments also use flywheels coupled to motor-generator units as storage[4]. The second important aspect is to avoid operating the engine in very unfavourable conditions. These are mainly engine idle (start-stop approach), and low engine loads with low engine efficiency. Replacing such ICE operation by electric driving can save fuel and hence tailpipe emissions of any kind. Furthermore, electric boosting can improve the transient response of the drivetrain while the ICE can change its operating point less rapid, which enables an optimised control of emissions and efficiency of the ICE during its transit from one operating point to the other.

In contrast to micro- and mild hybrids, full HEV enable electric driving over some distance, which may soon become a prerequisite to entering certain urban areas depending on the ICE type installed.

Therefore, we expect a further rapid increase of HEV registration numbers. Although it is not very likely that internal combustion engines will become completely banned after 2030[5], we expect that about any newly registered ICE powered vehicle will allow to be driven just electrically for some reasonable distance.

FCEV

In contrast to the HEV above, a Fuel-Cell Electric Vehicle replaces the internal combustion engine by a fuel cell. It can employ the fuel-cell in two ways:

- The FC can be used as a range extender in a BEV. In this case the main power unit is the battery that is usually recharged from the grid in parking. The FC will just be engaged to provide electric power when the battery state of charge turns low. This enables using a rather small fuel cell operating at quite constant load. Its power exceeding the current needs to drive the vehicle will recharge the battery. Otherwise it will provide a share together with the battery when more power is required to propel the vehicle. Depending on the capacity of the fuel cell, the dynamics of the vehicle may become restricted in case of low SoC.
- FC as main power unit in a fuel-cell hybrid electric vehicle, FCHEV. In this case, the FC is operated in a duty cycle with almost the same dynamics as the powertrain. However, a battery takes the role of a power buffer to smoothen the load profile requested from the FC. The battery will provide additional power in tip-in situations and be recharged by regenerative breaking and perhaps the FC ramped down less rapidly.

Aspects of layout and component dimensioning are

- Size, cost and weight of battery
- Package for FC system and heat exchangers
- Package for hydrogen tank
- Required vehicle performance and range

Despite significant progress in carbon fibre composite hydrogen storage tanks, the long-lasting storage of hydrogen remains a challenge. The molecule is about the smallest of all and manages to diffuse across many metals and small roughness in valves and seals. Tank pressure often ranges around 70 MPa. It consumes about 12% of the heating value to compress hydrogen to this level, which has a detrimental impact on the overall efficiency. Obviously, repeated pressurisation to different levels may occur during transport and decanting from one tank to another.

PHEV

Plug-in hybrid vehicles can be considered a hybrid of BEVs and HEVs. The battery of a PHEV can be charged not only by recovering kinetic energy and by the internal combustion engine, like in a HEV, but also from the grid like a BEV. In the intention of providing more electrical range, PHEV typically have a larger battery than HEV, which makes them heavier and increases their rolling resistance. Consequently, the energy consumption for driving increases with electric range and battery capacity.

According to present legislation that is based on T2W rating, the electric energy taken from the grid is regarded CO_2-free. If however PHEVs are not charged from the grid, their heavier battery will make them consume more fuel than an HEV with the same ICE but shorter electric range.

As shown in Figure 4, PHEV (and BEV) must use electricity mostly from renewable sources in order to achieve better lifecycle GHG emissions than a conventional Diesel engine. In particular PHEVs with a short electrical range are beneficial because of less rolling resistance and smaller carbon footprint in battery production.

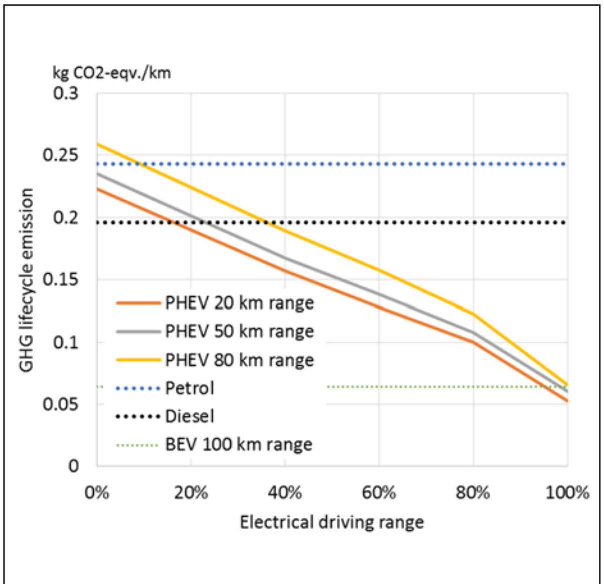

Figure 4: Impact of electrical driving range of PHEV utilising electric power from 100% renewable sources[6]

But as the cited study mentions, this will increase dramatically the number of charging cycles and thus shorten the battery life. If then a battery replacement becomes necessary, the GH lifecycle emissions of such PHEV increase again. The GHG emissions for 100% electric operation indicate the emissions due to vehicle production, of which a significant portion is attributed to the production of the battery.

Depending on how rigorously a PHEV is recharged from grid, the fuel may remain in the tank for quite a long time causing degradation of the fuel or having fuel of the wrong season in the tank with according control problems.

PHEV models in the market today can be split into two major categories:

- BEVs with range extender, like e.g. BMW i3. These cars allow a full operability on battery power. The internal combustion engine is intended to only prevent low state of charge emergency.
- HEVs that can be used like BEVs, like Porsche Cayenne S E-Hybrid, BMW i8, Audi A3 e-tron. These cars provide full performance only when the internal combustion engine is engaged. BEV operability is provided for urban operation in some cases up to motorway speed.

Different energy sources for different driveline types

Obviously the different types of vehicle drivelines described above use different source of energy to move. BEV and PHEV use direct electric energy from the grid (fully or to a certain extent), FCEV use hydrogen, which should be generated ideally from excess renewable electric energy. Lastly, the HEV drivelines (it is assumed that 100% of future vehicles will contain some kind of electrification to increase the total driveline efficiency) use some kind of liquid or gaseous fuel. At present, the latter are mainly from fossil sources with some more or less efficient bio-fuel content added to reduce the effective CO_2 emission.

The German federal environmental agency (UBA) published the report about a study on the environmental impact of electric vehicles (ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, 2016). It yields that the total CO_2 equivalent GHG emissions of the different vehicle types are currently not much different, when the German energy mix is considered. Major differences can be seen in the greenhouse gas emission arising in production of the different drivelines. Furthermore, the ratio between the emission from fuel supply and distribution to the in-operation emissions of the vehicle changes significantly between the different drivetrain concepts, in which the numbers behind the column refer to the possible pure electric vehicle range. When BEV and PHEV run on electricity generated from German primary energy mix in 2012, the Diesel ICE based vehicle turns out to have the lowest lifecycle GHG emissions. If however, PHEV and BEV concepts utilise 100% renewable energy for driving, PHEV and BEV have a large advantage, the lowest GHG emissions among them are shown for the BEV with 100 km range because of its lower battery weight.

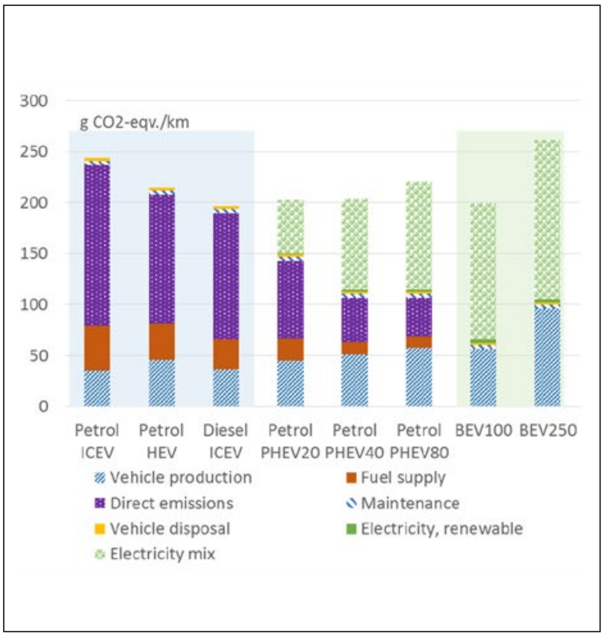

Figure 5: Greenhouse gas emissions of the evaluated vehicle concepts under average conditions in Germany (electric energy mix for 2012); vehicle life 168.000km[7]

By 2030, the electricity decarbonisation progress changes the picture to the advantage of electric vehicles even when using electricity based on the primary energy mix, because the share of hard and soft coal will have shrunk by almost 50% compensated by increase of renewables and gas (ifeu - Institut für Energie- und Umweltforschung Heidelberg GmbH, June 2013).

What does not change according to these two studies, however, is the higher GHG emission of long electrical range PHEV (20 - 80 km) and BEV in vehicle production. Also, further unfavourable environmental impacts are found from battery production, such as acidification and particulate emissions higher than for ICE powertrains. This finding as well as the total use of resources for the total vehicle life also published by UBA and IFEU (Figure 7), showing significant drawbacks for the cumulated raw material use in g/km, lead us to the question which amounts in these CO_2 emission can be replaced with renewable energy and, therefore, can be effectively removed from this balance on a complete vehicle lifetime basis.

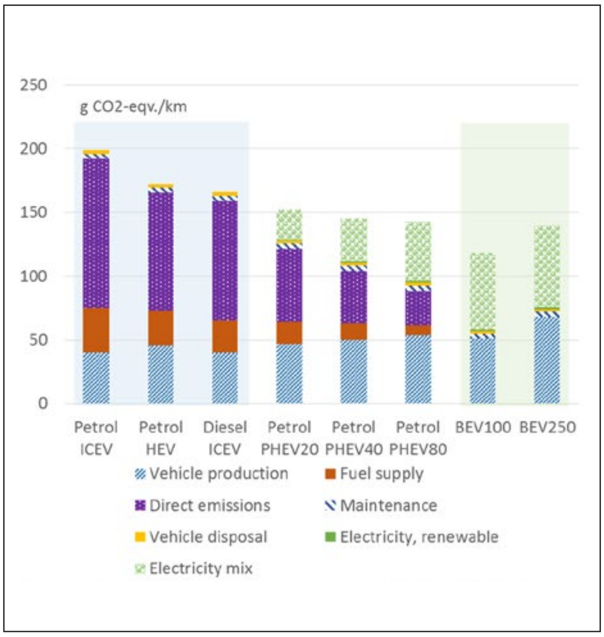

Figure 6: GHG emissions of evaluated vehicle concepts in scenario 2030, pure renewables full green area, German energy mix 2030[8] all green area, vehicle lifetime 168000km[9]

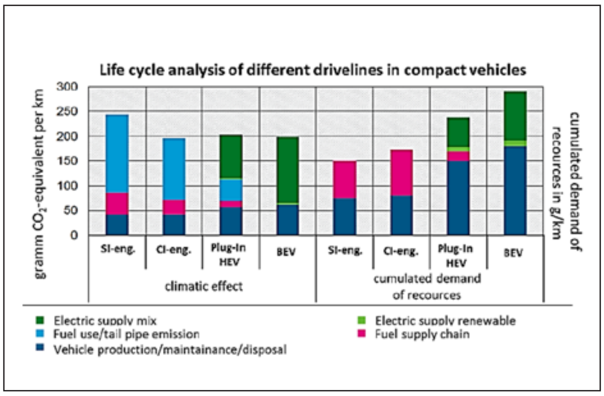

Figure 7: Climatic effects and raw material usage for different drivetrain concepts (base year 2014; electric energy mix 2012)[10]

Why is liquid energy storage needed?

Projecting a major transfer to renewable energy for the year 2050, the following paragraph will explain the total energy consumption and some major trends for Germany based on combined information from various publications and sources.

The total electric energy consumption of Germany per year was 528 TWh[11] (in 2010). Taking into account that in general efficiency in electric devices is increasing (see LED technology and others), still automation in production and general production capacities are rising. So for 2050 the need for electricity (without the additional need for electrified transport) is assumed to be rather constant.

For transport sector the energy consumption per year was 728 TWh[12] (in 2015). Assuming an increase of transportation demand by 30-40% (also according to the ERTRAC road map) and assuming further an increase in efficiency of the energy usage in the transport sector by a higher degree of electrification and improved hybrid powertrains, we assumed also in this sector a constant energy need for 2050.

For 2015, the German federal environmental agency published a total sum of primary energy consumption from all sectors in Germany of 2466 TWh[13]. The potential of renewable electricity in Germany is assumed to be 629 TWh[14] which exceeds the electrical use by ~20%.

But the electrical energy generated from wind and solar is also not always matching the usage profiles. Therefore, ~100 TWh need to be or can be used for long term storage such as power to fuel or power to gas. It is furthermore assumed that Germany has a potential of ~70 TWh of renewable fuels or other hydrocarbons from biomass (only 2nd generation fuels).

This means that there is a lack of 1767 TWh of renewable energy in any form. As German policy is not favouring import of nuclear electricity on the long term and furthermore Europe in total will not be able to cover fully its energy demand from renewables (except for some countries like Norway or maybe Spain, the latter of which has a quite high potential for solar energy), the only solution at least for Germany is a renewable energy import combined with measures to reduce the total energy consumption.

This leads without doubts to areas with high energy potential such as North Africa or others. As widely known, renewable energy comes in most cases as electricity, which is hard to transfer over large distances. The first step of chemical storage leads through electrolysis on rather good efficiency (70-80%) to hydrogen. Hydrogen again is not very easy to transport in an efficient way by its very low density. Liquefying hydrogen also means a significant energy consumption (about 30% of its energy content) and furthermore makes the transport chain very costly. Therefore the most meaningful storage is the further transfer to methanol. Its production leads to some additional energy losses against gaseous hydrogen (16%), but enables a wide distance transport of a high energy density liquid through pipelines and ships without major efforts.

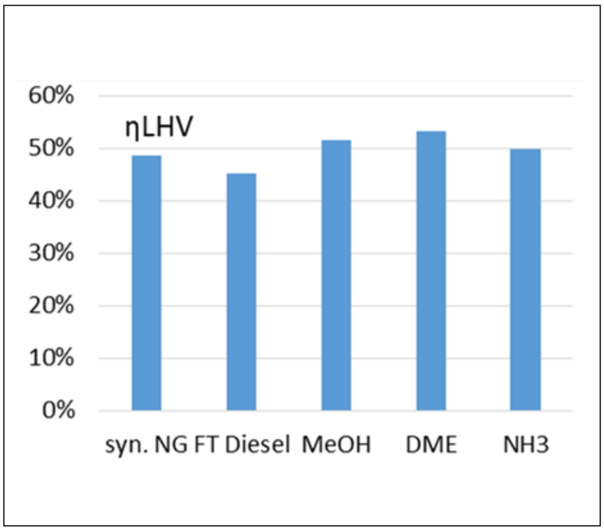

Figure 8: Overall conversion efficiencies for different power-to-fuel routes based on flowsheet simulations[15]

If now the starting point for imported energy is Methanol, the question is how its valuable energy can be used most efficiently. There are different options available:

- Central re-electrification through turbines or fuel cells and usage as electric energy incl. grid and battery charging and discharging losses plus the additional transport of the heavy battery
- Local/on-vehicle re-electrification through range extender or fuel cell or engines, which at least reduces/replaces the grid losses by methanol distribution, reduces the battery weight of the vehicle and reduces the charging & discharging losses to a minimum

- Fuel usage in high efficient hybrid drive trains which enable long distance heavy load transportation on existing fleets and infrastructure

Comparing the W2W energy balance and assuming all pathways start from Methanol and all emitted CO_2 as part of a circular usage, the central re-electrification and usage in BEV's leads to an estimated total efficiency of ~ 34%, the on-vehicle electrification leads to an efficiency of 36% assuming a Methanol FC efficiency of 40%. At the same time modern hybrid powertrain concepts also show efficiencies above 35% which makes them again competitive.

Additionally, it must be taken into account that all three paths will improve over the next years, which might lead to more significant benefits for one or the other (especially things like battery production and recycling). But taking into account the usability of the existing infrastructure and the possibility to burn electricity-based "designer" fuels very clean and efficient, this path should at least be taken into account also considering the time pressure existing in the context of global warming and the need for fast CO_2 emission reduction with affordable total invest.

These assumption does not take into account the actual use of crude oil and other fossil sources in the chemical industry, yet. To also de-fossilise this industry, additional renewable energy and chemicals are needed increasing the market demand for renewable HC-based chemicals.

Towards future zero CO_2 mobility

Assuming that beyond 2050 all energy used in mobility needs to come from renewable sources, the question is which concept leads to the least environmental impact. From the point of primary energy consumption, Figure 9 shows an estimation, which kind of energy source for transport leads to which energy consumption. The use of biogenic sources to support the liquid fuel production is not taken into account in this estimation. All energy carriers in this comparison are based on electric energy and CO_2 from central sources, which is used to generate Power-to-X components.

Starting from a base vehicle with curb weight of 1400 kg, Figure 9 shows different passenger car vehicle driveline concepts with the range of the

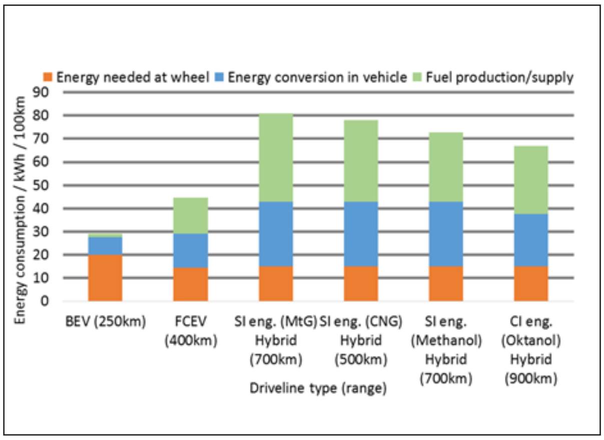

Figure 9: Estimation of primary energy consumption of different driveline types (base vehicle weight 1400 kg)

vehicle put in brackets behind each type. As it can be seen, the BEV having a significantly higher weight due to the battery consumes significantly more energy (~25%). It is assumed that all vehicles have enough electrification to reduce the braking losses to a minimum. Compared to a hybridised gasoline vehicle, the fuel cell vehicle is slightly lighter due to the assumed differences in the FC stack weight over the gasoline ICE. Accordingly, it consumes slightly less energy compared to the ICE drive vehicles. As a next step, the energy conversion is evaluated, which leads in sum to very similar results for the FCEV and the BEV. The ICE driven vehicles end up at a roughly 30% higher energy consumption. Considering additionally the fuel generation, the ICE driven variants end up at roughly twice the energy consumption, whereas the FCEV has a roughly 50% higher consumption of electric energy.

This is of course only valid if the electric energy used in the vehicle is stored directly from renewable power generation (see also Figure 10). As soon as electric energy has to be buffered in fuel storages, the primary energy efficiency of electric vehicles suffers from re-electrification losses and repeated grid and charging losses and reaches the same or higher levels than conventional drivetrains.

At this point the power generation on the vehicle or the direct combustion is beneficial. Battery storage does reduce this issue, but we considered giant battery plant also critical from cost and environmental view.

Adding now the vehicle, driveline and battery production to this scenario and additionally the

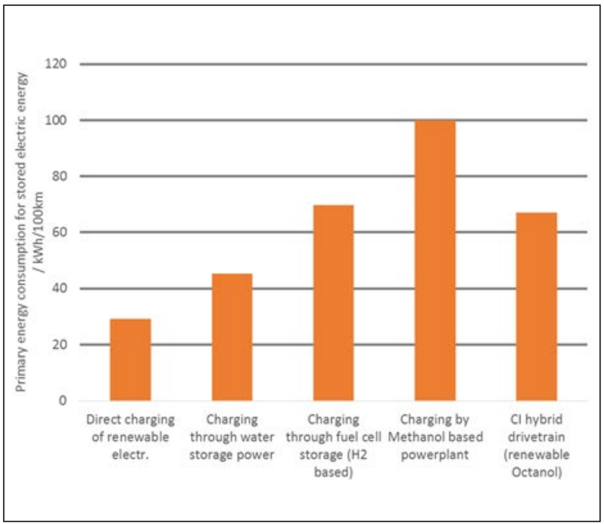

Figure 10: Estimation of primary energy consumption of different types of (electric) energy storage

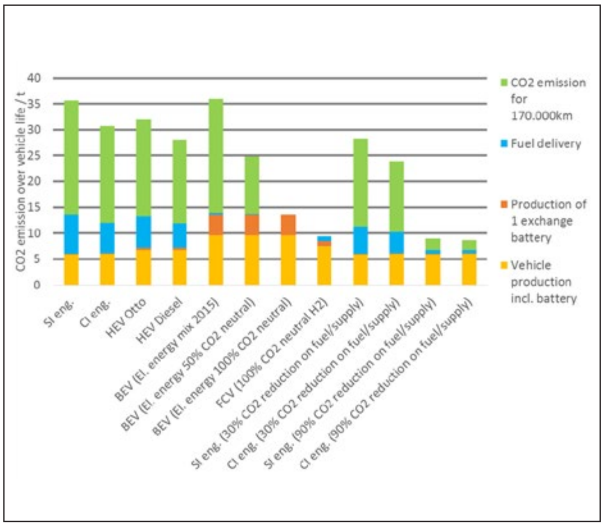

Figure 11: Estimation of lifetime CO_2 emission of different driveline and fuel supply variants for a total life of 170.000 km

availability of electric energy, the final evaluation changes significantly.

Based on recent data of the German federal environmental agency about CO_2 emissions in 2015[16], we made an estimation for the CO_2 emissions of different vehicle types assuming a vehicle life and usage of 168.000km. As Figure 5 already showed, for Germany in 2015 there is no major difference between a gasoline car and a BEV over lifetime. At this point a hybridised Diesel vehicle would clearly win a comparison of total CO_2 emission. When assuming the FCEV and BEV would use only renewable energy (see Figure 11), the energy consumption of the FCEV would still be higher, but this is not reflected in the CO_2 balance. However, the production of the battery has such a high impact on the CO_2 emission that the FCEV would turn out ~30% better than the BEV. If now efficient hybrid topologies for gasoline and Diesel vehicles are used and it is assumed that the fuel used can be 90% CO_2 neutral, the total CO_2 output over the full vehicle life comes again very close to the BEV running on renewable electricity.

The future will of course change the CO_2 output from production processes. Battery reuse and recycling will hopefully help to improve the total energy usage, so this evaluation needs to be monitored over time. From today's point of view, ICE powered drivetrains can be environmentally similar efficient as green electricity driven BEV's, if renewable liquid fuels are available from energy imports, from energy storage or other sources.

It shall be pointed out that other effects like infrastructure cost, PM emission from raw material harvest and many other environmental impacts from production and especially battery production processes are seen very critical in the study mentioned[17], but also in other studies.

In the comparison above, the CO_2 balance of BEV suffers from Germany's carbon-loaded primary energy mix for electric power. A comparison of the powertrains under the assumption that all energy carriers for driving could be carbon-neutral, requires an abundance of regenerative energy beyond the EU target of 97% for 2050, because the production of any e-fuel requires more energy input than just charging a battery. However, producing batteries in Europe will also require the related energy supply, which has to be considered in a holistic approach.

As long as regenerative fuels are in short supply, they should preferably be used where they are inevitable, i.e. in long-haul and aviation, whereas mobility in urban areas and around is prone to replace combustion engines by battery power.

A thoroughly intensified establishment of electric powertrain component recycling will mitigate the energy requirements and other detrimental environmental impacts of electric vehicles.

Summary

Collecting all given information and taking into account a post-2050 target of 100% renewable based energy transport, we would summarize the situation as follows: Electric vehicles are most efficient in use of renewable electricity if they are charged directly from the grid without the need of interim electricity storage. Their main present drawback is the environmental impact of the battery production. Therefore BEV's should be used in short range transport regimes, where they can live with a small battery. This also helps the total energy consumption due to less vehicle weight.

In case electricity has to be stored on a regional level, the second main option are FCEV. They have in general still big improvement potential, but already show a very good conversion efficiency. They can be combined with a relatively small battery, which makes them a rather light solution with very low environmental impact. Also the H2 production from excess electricity is rather efficient, and along with battery power plants, H2 electrolysis is a key element of storing temporary excess electricity inevitable to guarantee grid stability in renewable electricity systems. Still the drawback is that the transport and refuelling of H2 is rather inefficient and complex, which limits the supply of H2 to rather short distances.

The third option especially interesting for large scale energy import is the transfer of renewable electric energy into liquid fuels (which can be methanol or other fuels such as DME/OME or higher alcohols). The drawback of course is the higher primary energy use for the production of such fuels. But liquid fuels are the most efficient energy carriers for long term storage or long distance energy transport. Especially the methanol route seems very attractive among the liquid energy carriers, when regenerative energy has to be imported from remote areas. The use of such energy carriers as fuels will then be most efficient in long distance and heavy transportation (aviation, shipping, but also in heavy duty on road transport). Need for long distance passenger cars will remain. Also here the use of such fuels in high efficient ICE or FC based driveline concepts will be more environmentally friendly and efficient than their re-electrification to the grid for use in BEV's. Fundamental assumption for future ICE based (P) HEV vehicles is of course the use of very clean engines with extremely high efficiency and very low overall environmental and health impacts.

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Acronyms

FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicles
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
PHEV	Plug-In HEV
RES	Renewable Energy Sources
SoC	State of Charge
T2W	Tank-to-wheel
W2W	Well-to-wheel

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Contact

Christof Schernus, Dipl.-Ing.
schernus@fev.com

Thorsten Schnorbus, Dr.-Ing.
schnorbus@fev.com