Interplay of All Drive Types

The forecast for the number of cars that are expected to have an all-electric powertrain by 2030 now seems more unrealistic than ever, above all in Germany. Uncertainties in the energy supply and in the success of these vehicles in the market are just too great. At the same time, it seems certain that the use of synthetic fuels will enable other drive systems to make an important contribution towards climate protection. This may well be a turning point in the climate debate.
In many places, for example in Germany, the battle against climate change is similar to the fight against the coronavirus pandemic: Recognized experts recommend sustainable and systemic measures – but politicians often implement them in a populist manner or succumb to the temptation of simplified, ideologically motivated approaches. The bar for electric mobility is set very high: It is expected to save the climate, determine the mobility of the future, and at the same time provide functionality that is at least as good as other types of drive systems. That all sounds wonderful at first. However, the expectations are so great that they do more harm than good to electric mobility, because this can only really exploit its full potential if there is a mix of different drive systems. It is probably for that reason that the EU has recently been calling for the rapid introduction of synthetic fuels and biofuels. In Germany, Agora Energiewende has for the first time classified these energy resources as being important for achieving the climate targets. Even the current State Secretary in the German Federal Ministry for Economic Cooperation and Development and former State Secretary at the German Federal Ministry for the Environment, Jochen Flasbarth, who has positioned himself as a major electric mobility lobbyist over the past few years, recently appeared before the press with a similar message. And in its coalition agreement, the new Federal Government also advocates that “only vehicles that can demonstrably be fueled with e-fuels can be newly registered” [1].

A noticeable and sustainable reduction in the global CO₂ emissions caused by the transportation sector is feasible. But this cannot be achieved with electric vehicles alone. It also requires the widespread use of liquid or gaseous energy resources on a sustainable basis. This view is not exactly a popular one in public discussions on environmental policy, which tend to be very one-sided, but it is nevertheless a sine qua non. In Germany alone, there are currently 57 million vehicles, of which around 48 million are passenger cars. In the EU, there are around 250 million vehicles on the roads, and globally the figure is around 1.4 billion. An environmental policy that fails to take this existing stock into account is not constructive, because many of these vehicles will
still be on the roads in 20 years’ time – also in Europe. Even high incentives in the form of an “environmental bonus” for the purchase of an electric car do not compensate for the lack of driving range and the high purchase price because, even in wealthy Germany, the average gross wage of full-time employees was 3975 euros a month in 2020 [2] – and these people must also be able to participate in mobility. Added to this is the problem of the inadequate infrastructure in the power grid. Of course, it may well be possible to generate sufficient wind and solar power, but unfortunately this cannot be stored because the facilities for this are not yet available. And the electricity cannot be fed to residential areas either, because in many places the medium-voltage power lines are not designed to reliably supply a large number of electric vehicles in every street. What is more, this does not even take any account whatsoever of industrial users, who are also expected to convert to electricity from sustainable sources.

SYNTHETIC FUELS ARE SUSTAINABLE

The energy losses in the production of hydrogen from green electricity, for example, are often cited as a so-called game stopper compared to battery-electric mobility. However, as Prof. Michael Bargende (FKFS) points out, it must be considered that in the future not only will green electricity have to be temporarily stored in order to ensure security of supply, energy will also have to be imported in the form of chemical sources of energy. “In both cases, conversion back into electricity would result in such high efficiency losses that direct usage is by far the more efficient solution. If we switch from hydrogen to e-fuels, then – contrary to some opinions – there is practically no loss of efficiency, because we have to take into account the considerable energy losses in the use of hydrogen, from production to the vehicle tank,” is Bargende’s conclusion [3]. Synthetic fuels are therefore a sustainable solution that does not require a new global infrastructure and one that not only guarantees an urgently necessary reduction in CO₂ from existing vehicles, but will also be decisive for a systematically important and sustainable form of mobility of the future. Also for the vehicles themselves, the difference is much smaller than is often suggested if the actual real driving efficiency is considered and the current state of technology is used as a basis.

In this context, the electrolyzer test field funded by the EU and the Federal State of Bremen at the Hydrogen Center of Excellence Bremerhaven is an important technology carrier. “The possible applications of green hydrogen,” the initiators say, “range from the generation of synthetic fuels for vehicles and the substitution of methane for the gas heating of buildings to its use as an alternative to fossil fuels in industry [7]. The motivation of the initiative’s partners is based on the rules of physics: “The availability of solar and wind energy varies from day to day. As a result, an energy supply which relies to an increasing extent on renewable energies requires a storage medium in order to compensate for the natural fluctuations and to retain surpluses. Hydrogen as a molecular energy store, which is converted back to energy through combustion, is regarded as a central component of the energy transition” [8]. If this expertise could now be exported to countries that have a high yield of wind and solar energy, this could become the key for future primary energy imports and at the same time strengthen Germany as a technology location.

MISSING THE TARGETS WITH ALL-ELECTRIC VEHICLES

Against this background, the target set out in the coalition agreement of the newly elected German federal government to achieve the figure of “one million publicly accessible charging points by 2030 with a focus on fast-charging infrastructure” [9] and “at least 15 million fully electric passenger cars in 2030” [10] must be viewed critically. It not only as expected, a BEV has a higher efficiency; however, from a real driving perspective, the various types of drive systems differ only slightly.

Vehicle efficiency in real driving conditions (state of the art)

| Supply | Sustainable energy carrier | Operation | Expected range efficiency (passenger car) |
|--------|---------------------------|-----------|-------------------------------------------|
| BEV    | H₂ (pure)                 | Load on the wheel (load profile) | 50 – 65 %¹  |
| ICE (electrified) | H₂-Tank + FC | Conditioning battery | Full-year view |
| FCEV   |                           | Parasitic losses and auxiliary consumers | 40 – 45 %² |
|        |                           | Air conditioning vehicle | 40 – 50 %   |
|        |                           | On-board computing |  |
|        |                           | Germany, 15,000 km/year |  |

Note: Plug-in hybrid combines BEV + ICE (electrified) ¹ Calculation according to [1, 2] ² Potential of technologies known today according to [3]
requires an infrastructure that can be created only with high levels of investment and implies at least a questionable CO₂ advantage of electric energy sources, it also assumes a high degree of public willingness to buy battery-electric vehicles, which even in a heavily regulated market is currently not apparent. As almost three million new vehicles are registered in Germany every year, this would mean that around 60 % of sales would have to be BEVs, which does not seem very realistic even if the number of vehicles actually increases by almost 4 %, as some are forecasting. At the moment, around 517,000 BEVs and 494,000 PHEVs are registered in Germany, which corresponds to a proportion of 0.64 % and 0.58 % respectively of the existing number of vehicles registered (as of October 2021) [11].

The EU forecasts a share of 20 % for electric cars in 2030 in all member states, with a market share of 50 % for FCEVs and BEVs together. It is often unclear whether the respective authors only list BEVs or also include PHEVs and FCEVs. However, this forecast seems very optimistic as it contains many unknown factors. And even if the forecast is correct and if, in addition to the energy transition, a transition to intermodal mobility is completed at the same time, there will still be a large number of vehicles on the market that require gaseous or liquid energy sources in order to meet functional and systemic requirements that must also be taken into account [12].

One of these above-mentioned unknown factors in the forecast is the amount of electricity that will be available locally. An average filling station on a German autobahn has around twelve fuel pumps. According to Bargende, if each pump can supply fuel at a rate of 35 l/min, this is equivalent to 18 MW per pump. If we assume that each charging point supplies a charging power of 6 MW, a typical autobahn filling station with around twelve fuel pumps would require 600 fast-charging points with 72 MW of charging power if it is to approximately achieve the vehicle refueling throughput that is common today also for fast-charging BEVs. Bargende: “Even assuming a factor of 3 for the energy consumption advantage of a BEV compared to a vehicle with an internal combustion engine, based on the existing fleet, we will still need a connected electric power supply of at least 50 to 60 MW at peak times. It is hard to imagine that this is feasible” [13, 14].

NO FUTURE WITHOUT OPENNESS TO ALL TECHNOLOGIES

It is probably for that reason that the German federal government is promising that “according to the proposals of the European Commission, only CO₂-neutral vehicles will be registered in the transportation sector in Europe in 2035” and is supporting “the introduction of an ambitious and implementable Euro 7 emissions standard” [15]. This is to be “open to all technologies” [16]. And this is where the latest generation of synthetic fuels and biofuels will come into play. It has obviously now been recognized that these liquid and gaseous sources of energy can make an equally important contribution to a sustainable reduction in CO₂ to that of electric energy. Produced using sustainable energy at the world’s “sweet spots,” they are available as blends or in a pure form – and not only for existing vehicles, but also for new ones. Thermodynamic energy converters running on synthetic diesel and gasoline or on hydrogen have an equally defossilizing effect on the overall cradle-to-cradle balance as fully electric drive systems. According to Prof. Uwe Dieter Grebe (AVL), the climate-relevant footprint over the entire life cycle using today’s energy sources and today’s energy mix is 31 t of CO₂ for a mid-size car with an internal combustion engine, compared to 24 t for a BEV and 32 t for an FCEV. If synthetic fuels and hydrogen as well as electricity from sustainable sources are used, the three drive systems are almost on a par, even if only limited availability is assumed for eFuels in passenger cars [17].
If sustainable energy resources are used, the CO₂ footprint of various energy converters is almost the same from an LCA perspective.

| Hybrid electric vehicle | Battery electric vehicle | Fuel cell electric vehicle |
|-------------------------|--------------------------|----------------------------|
| 24 t                    | 8 t                      | 12 t                       |
| 31 t                    | 24 t                     | 20 t                       |
| Efficiency              | Electricity mix          | Fuel cell production       |
| -10 %                   | -75 %                    | -50 %                      |
| E-fuels, Biofuels       | Battery production, Mat. and recycling | Hydrogen source |
| <10 %                   | -50 %                    | -90 %                      |
| Road to zero            | Production               | Renewable hydrogen         |
| Potential CO₂ reduction | - likely to become carbon neutral by 2050 | as part of national energy planning |
|                        | - Efficiency of ICE in HEV 50 % possible | will significantly improve lifecycle emissions |
|                        | - PHEV: high EV-range will enable high electric share | - CO₂ emissions of battery production will remain a major factor |
|                        | - E-fuel unlikely to be available for pass. car before 2050 | - Production CO₂ is higher than ICE but lower than BEV |

| 2030 + target | 6 – 20 t |
|---------------|---------|
| Production    | No known limitations on raw material |
| CO₂ emissions | as part of national energy planning |
|               | will significantly improve lifecycle emissions |
|               | - Production CO₂ is higher than ICE but lower than BEV |

Based on the premise that the discussion is currently at a crucial turning point, its focus on the impact on the climate is slowly gaining maturity and structure, for example by ending the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].

Also when it comes to climate protection, scientific expertise is confronted with a dangerous mixture. Political decision-makers prefer not to listen to the scientists, while in a media world that is geared toward entertainment or the mixing of climate and air quality. Due to the numerous facts that are available on the overall impact of modern energy sources and converters, as well as on the demonstrable market maturity of synthetic fuels and the future viability of modern internal combustion engines that make use of these sustainable fuels, the potential with regard to achieving air quality targets would also have to be evaluated in an unbiased manner for all types of drive systems, as is shown by a more detailed article at SP-Online [18].
OPINION

“It is good that some areas in politics and the media are rethinking things, because only a full reappraisal of the complex structures will lead to success. We can only hope that this rethinking process is sustainable, because only when the complex structures are penetrated can a targeted defossilization succeed. That is possible only with — and not against — the expertise of science and technology and only with a concerted effort including all types of drive systems.”

Christian Beidl
is Director of the Institute for Internal Combustion Engines and Powertrain Systems at TU Darmstadt.

Alexander Heintzel
is Editor-in-Chief of the ATZ/MTZ Group.