27th INTERNATIONAL CONGRESS OF MECHANICAL ENGENEERING
COBEM 2023

ABCM Brazilian Society of Mechanical Sciences and Engineering
27th ABCM International Congress of Mechanical Engineering
December 04-08, 2023, Florianópolis-SC, Brazil

COB-2023-2388
FUTURE ENERGY SOURCES OF MOBILE DRIVE SYSTEMS

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Abstract. *This article shows that the need to replace fossil fuels varies from region to region. In Europe, the focus is currently on CO_2 neutrality. However, in addition to these environmental reasons, security of supply and cost are becoming increasingly important. There are several types of renewable fuels. These include bio-oil (biodiesel) and bio-ethanol. On the other hand, "green" electricity from wind, water and solar power is becoming increasingly popular. The electricity is used directly in battery-powered vehicles or converted into green hydrogen, green methane or synthetic petrol (e-fuels). In addition to carbon emissions, energy availability and cost are important. A good example is the use of bioethanol in Brazil. Alcohol-based fuels have been used in Brazil for decades because of availability and price. In sunny or windy regions, the production of green hydrogen is interesting. Green hydrogen can be used directly in aircraft engines, internal combustion engines or fuel cells. As Porsche is demonstrating in Chile, it is possible to convert hydrogen into e-fuels on a large industrial scale. In addition to these considerations, political aspects are important. The direct use of solar and wind power in passenger cars is very popular in the EU. There are more and more battery electric vehicles (BEVs) on the market. BEVs have the best possible efficiency. Renewable electricity is stored in batteries with little loss, and the electric motors are highly efficient. The intermittency of solar and wind power is a problem in this respect. A major problem is that battery capacity is too small to compensate for these fluctuations. The cost of batteries is also immense. For this reason, BEVs are subsidised by governments. At present, BEV sales in the EU are no longer growing at a progressive rate. One reason for this is the reduction in government subsidies. This also shows the importance of economic aspects. The fuels of the future will be diverse. This paper shows that the almost exclusive focus on BEVs in Europe is globally inappropriate. Depending on the region and social acceptance, different types of conventional and "green" energies will coexist. Aircraft engines, internal combustion engines and fuel cells run on fossil fuels and renewable substitutes. Depending on energy availability and costs, the direct use of green electricity in battery-powered vehicles will increase.*

Keywords: *Alternative fuels, e-fuels, bio ethanol, bio hydrogen, bio diesel, power to gas, power to liquid*

1. INTRODUCTION

The world's growing population is creating an unprecedented global demand for energy. Sunlight, stored in the earth millions of years ago, is currently the most important source of energy. These energies are oil, coal and gas, which cover 80% of the world's energy needs in 2020 (BGR 2022).

In the fight to reduce energy consumption and CO_2 emissions, engineers are doing two things. On the one hand, engineers are improving the efficiency of machines and systems. Of course, engineers have always been experts at optimising efficiency and saving resources. On the other hand, there is a growing realisation that efficiency alone is not enough. Energy availability and the possibility to store and transport energy, especially renewable energy, are becoming increasingly important.

Renewable energies are increasingly replacing fossil fuels around the world. This article shows the status of energy supply for passenger cars, aircraft and ships, but also the need for diverse solutions to replace fossil fuels in different regions of the world. In Europe, the focus is currently on making energy sources CO_2-neutral. This focus primarily takes into account environmental or climate-neutral goals. Nevertheless, environmental arguments should not be the only driving force, as security of supply, and, not least, costs are important criteria.

Whether the reason is sustainability, security of supply or cost, the share of renewables is increasing worldwide, Figure 1. On the contrary, Figure 1 shows that, depending on the region, fossil fuels will still be relevant in 2050. Depending on the future scenario (STEPS, APS, NZE), the demand for fossil energy can range from less than 20% to more than 55%. The Stated Policies Scenario (STEPS) shows the development that is generally implied by today's political attitudes. The Announced Pledges Scenario (APS) assumes, among other things, that all the ambitious targets promised by governments will be met in full and on time. The Net Zero Emissions (NZE) scenario is the most ambitious forecast and assumes that the 1.5°C target is fully achievable.

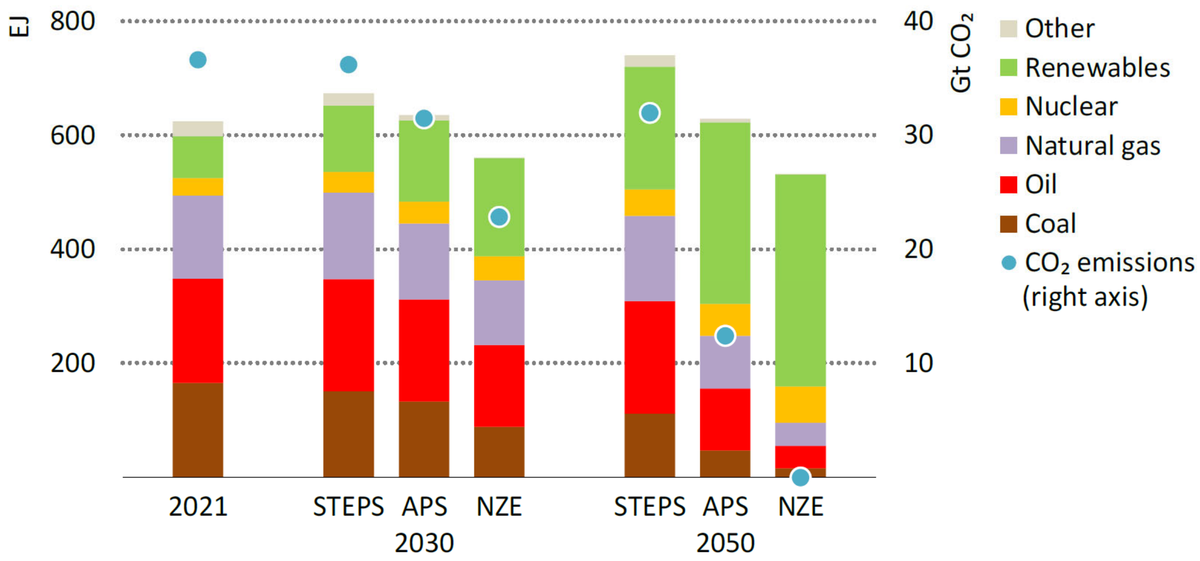


Figure 1. Total energy supply by fuel and CO_2 emissions by scenario, (IEA 2022)

2. CURRENT ENERGY SOURCES FOR MOBILE DRIVE SYSTEMS.

The following chapter gives an overview of the energy sources of today's land, water and air vehicles. The aviation industry presents a particularly interesting situation because aircraft must be light and often fly long distances (>3000 km). Regeneratively produced aviation fuel, known as SAF (Sustainable Aviation Fuel), does not currently play a significant role. SAF or biokerosene has only a very small share of about 0.1% worldwide (Witt, 2022). The situation is very similar in the EU, where the use of SAF is approximately 0.5% (Spiegel, 2022). Energy from hydrogen and batteries is even less common than SAF fuels.

Ships have the advantage of being able to transport large masses and volumes. They are therefore predestined to carry heavy batteries. However, this is not the case as 98.8% of the world's ships use conventional propulsion systems (DNV, 2022), Figure 2. There are almost no alternatives to diesel fuel, heavy fuel oil, petrol and fossil gas.

Alternative fuels in the shipping industry, such as LNG (liquefied natural gas), are easily confused with green fuels. LNG, LPG (liquefied petroleum gas) and methane gas are typically fossil fuels. They are used in modified internal combustion engines (ICE). Hybrid drives are efficiency-optimised combinations of ICE and electric motors. 100% battery powered ships are rarely used.

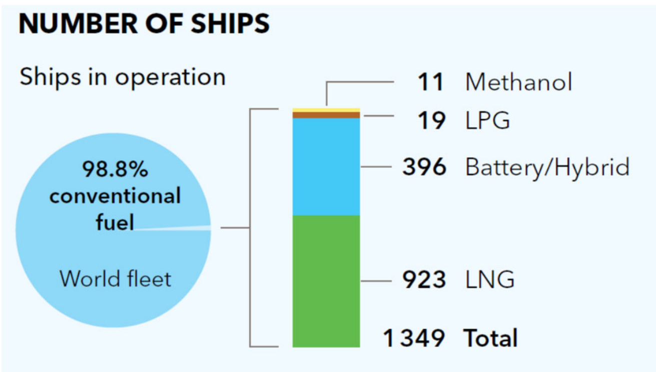


Figure 2. Use of alternative fuels and propulsion systems in the world fleet by number of vessels (Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG)), (DNV, 2022)

The situation is different for passenger cars. Unlike the transport sector, car buying behaviour is not primarily driven by cost, but also by emotion. In the following, the behaviour of buying a new car will be used to assess customer needs. Registration numbers show that, around 95% of all new passenger car registrations worldwide in 2021 will have an internal combustion engine (ICE) or an electrified internal combustion engine as a hybrid drive (hybrid electric vehicle - HEV, plug-in hybrid electric vehicle - PHEV, mild hybrid electric vehicle - MHEV); only 4.1% of cars will be new battery electric vehicles (BEV), (ABB, 2021).

Of course, BEVs have the best possible efficiency when it comes to converting electrical energy into mechanical energy. Where the electrical energy comes from is important here. According to the first law of thermodynamics, 1 joule of thermal energy (from gas, petrol or ethanol) is not equivalent to 1 joule of mechanical or electrical work. The high efficiency of BEVs is therefore logical, as electrical and mechanical energy are thermodynamically equivalent. The advantages and disadvantages of BEVs will be discussed later.

The popularity of ICE engines varies from region to region. A good example is the use of bioethanol in Brazil. Alcohol-based fuels have been used in Brazil for decades because of their availability and price. In 2022, the share of new cars with flex-fuel drive, i.e. running on either ethanol or petrol, will reach 83.2% (ANFAVEA, 2023). In Brazil, the consumption of renewable fuels is growing steadily, reaching a level of 412 thousand barrels of oil equivalent per day (BP, 2022). This corresponds to approximately 65.5 million litres of diesel fuel per day.

The situation in the EU is different. In 2021, 9.1% of new registrations will be BEVs, and less than 3% will use alternative fuels (including LNG and ethanol) (ACEA, 2022). Unlike Brazil, the EU is intervening heavily in the market with government subsidies. In 2022, new BEVs in Germany will receive a government bonus of up to €6,000 (about $6,300). From 2023, the subsidy will only be up to €4,500 (about $4,750). Whether sales of BEVs will continue to grow exponentially is a matter of debate, partly due to the falling subsidy premiums.

3. FUTURE ENERGY SOURCES FOR MOBILE DRIVE SYSTEMS.

As mentioned above, aircraft are almost exclusively powered by fossil kerosene, and there are very few SAFs available. In addition, battery-powered flying is not feasible in large aircraft and over long distances due to the energy density and weight of the batteries (Hartbrich, I., 2021). For this reason, the EU is introducing a quota for SAFs. The minimum proportion of SAF fuel must be 2% in 2025, 5% in 2030 and 63% in 2050 (European Parliament, 2023), Figure 3. It is clear that fully regenerative aviation is difficult to achieve with SAF alone. Another solution is hydrogen-powered aircraft. Well-known manufacturers such as Airbus are working on new types of hydrogen aircraft engines. One example is the conversion of the Airbus A380 to hydrogen engines. A prototype will be tested in the next few years, but there is no clear date for the start of series production. In summary, fossil fuels will continue to play an important role in the aerospace industry for decades to come.

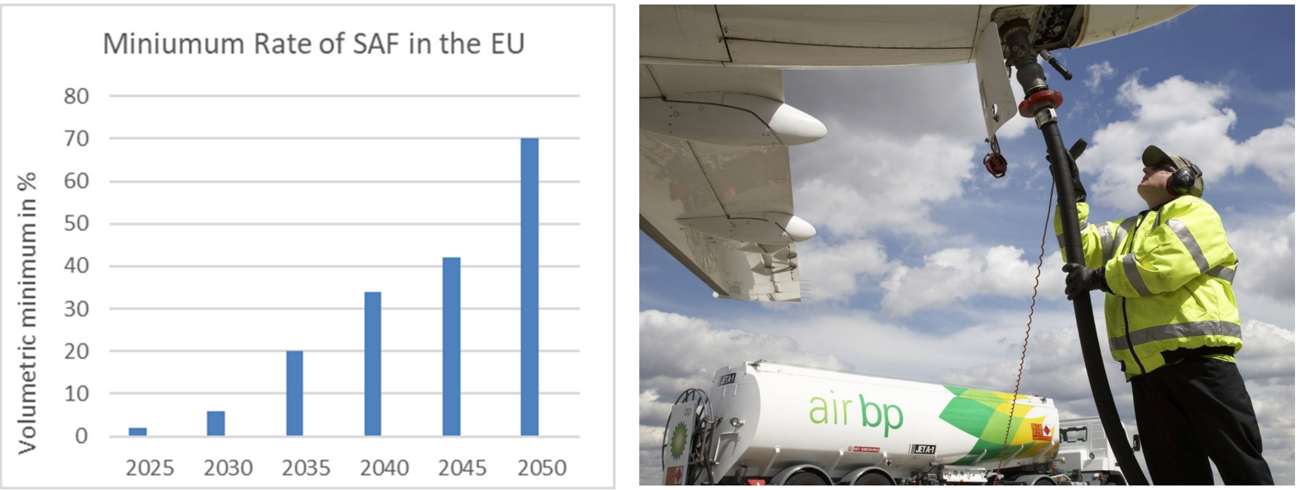


Figure 3. Left: "Minimum biokerosene quota announced by the EU from 2025 to 2050" (European Parliament, 2023) and right: "Illustration of a SAF refuelling (BP)

As mentioned above, 98.8% of ships use internal combustion engines, typically powered by fossil fuels. Although LNG, LPG or methanol propulsion systems are referred to as "alternative" propulsion systems in shipping, they are in fact modified ICE engines. The share of these alternative propulsion systems is growing, as shown in Figure 4: 1,046 new ships are currently in production that will be equipped with various propulsion systems, but mostly with internal combustion engines. Even the 417 newbuildings ordered with hybrid or battery propulsion systems do not change the situation much. In other words: 0.02% of the world's newly ordered ships will be battery or hybrid powered.

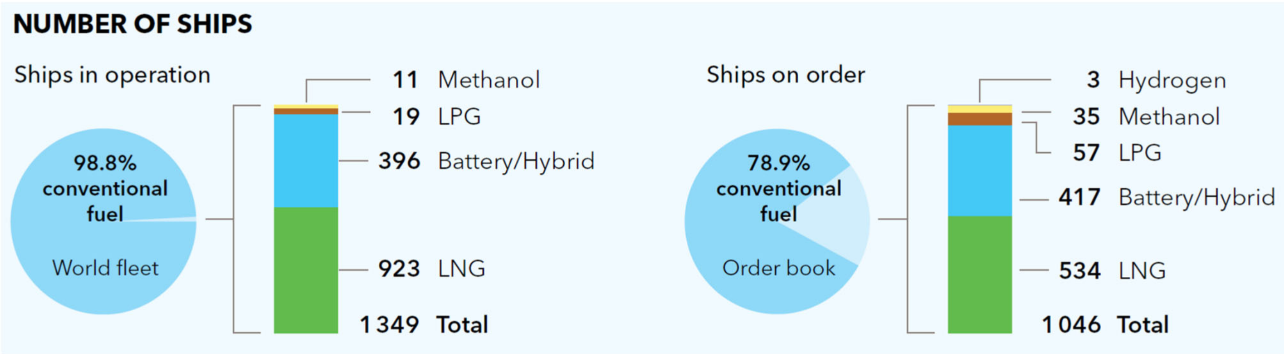


Figure 4. Current number of ships and newly ordered ships worldwide, June 2022, (DNV, 2022)

Figure 5 shows a Rolls-Royce hybrid propulsion system with an MTU marine diesel engine. A clever combination of combustion engine and generator increases the efficiency of the system. The serial hybrid system has a complete mechanical decoupling of the combustion engine from the ship's propeller. As a result, the ICE always runs at the best consumption point. The large diesel engine (coloured in blue) that is used in the hybrid drive system is clearly visible in the picture.

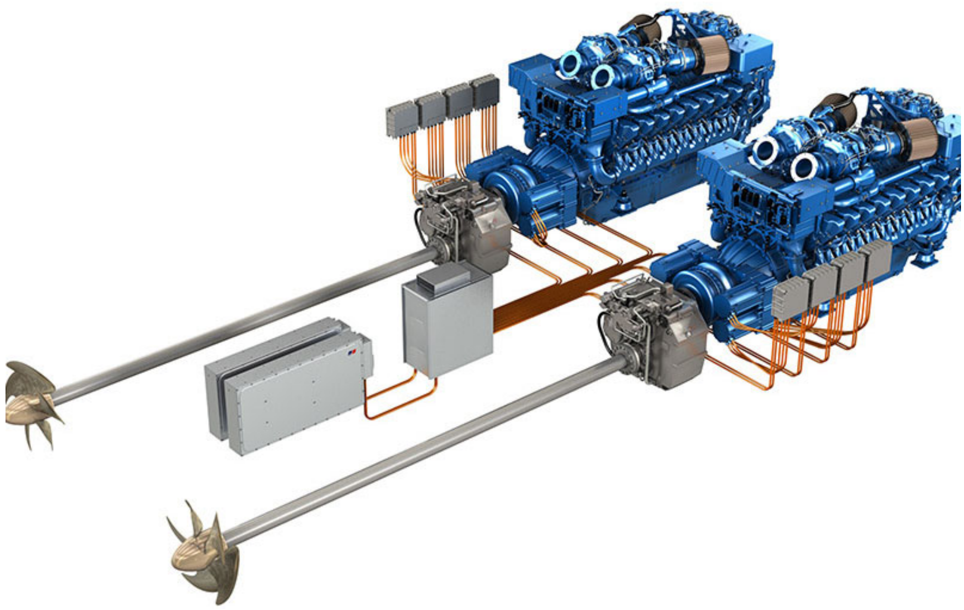


Figure 5: Illustration of a modern Rolls-Royce / MTU hybrid drive (in blue: heavy diesel engine and generator; in grey: electric machine and ship's propeller), (Rockenstein, S., 2023)

Passenger cars are of particular interest because of the high public profile of their propulsion units. That's why the engines are constantly being developed to reduce fuel consumption and emissions. In terms of emissions, legislation has become increasingly stringent around the world. In Europe, this can be seen in the standards from EU1 to the current EU6 and the future EU7, Figure 6. These standards limit pollutants like carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC) and particulate matter (PM). Pollutant emissions should not be confused with the emission of greenhouse gases such as CO_2.

	Pollutant g/km	Standard, Euro 1 7/1992	Standard, Euro 1 7/1992	Standard, Euro 2 1/1996	Standard, Euro 3 1/2000	Standard, Euro 4 1/2005	Standard, Euro 5 9/2009	Standard, Euro 6 9/2014	Standard, Euro 6 9/2018
Test cycle		NEFZ							WLTC
Gasoline engine	CO	3.16	2.72	2.2	2.3	1.0	1.0	1.0	1.0
	HC+NOx	1.13	0.97	0.5	-	-	-	-	-
	HC	-	-	-	0.2	0.1	0.1	0.1	0.1
	NOx	-	-	-	0.15	0.08	0.06	0.06	0.06
	PM	-	-	-	-	-	0.005	0.005	0.005
Diesel engine	CO	3.16	2.72	1.0	0.64	0.50	0.50	0.50	0.50
	HC+NOx	1.13	0.97	0.7	0.56	0.30	0.23	0.17	0.17
	NOx	-	-	-	0.50	0.25	0.18	0.08	0.08
	PM	-	-	0.08	0.05	0.025	0.005	0.005	0.005

Figure 6. Reduction of emission limits from EU1 to currently EU6 in Europe

In addition to stricter emission limits, the New European Driving Cycle (NEFZ or NEDC) has been replaced by the Worldwide Harmonized Light Vehicles Test Cycle (WLTC). This means lower emission limits and tougher driving cycles. At the same time, vehicle masses are increasing due to higher comfort and safety requirements. Despite heavier vehicles, stricter emissions regulations and tougher test drives, fuel consumption is trending down, Figure 7. The automotive industry and research institutions have done a great job.

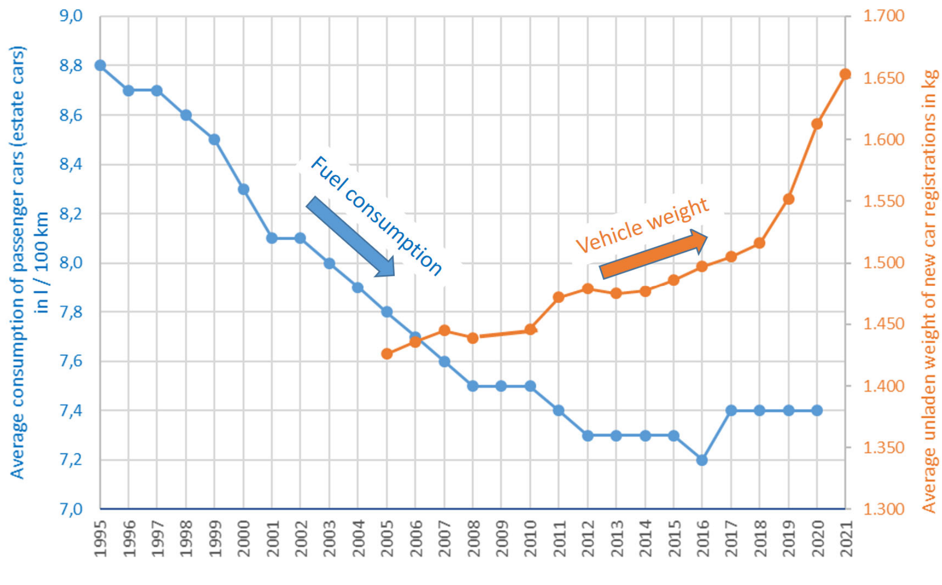


Figure 7. Development of the average consumption of the car fleet and the mass of newly registered passenger cars in Germany, data from (BMDV, 2021), (KBA, 2023)

As seen in the previous chapter ICE are common around the world and BEVs are only slowly replacing ICE vehicles. There are different market shares of new BEV, e.g. 4.1% worldwide (ABB, 2021) compared to 9.1% in the EU for 2021 (ACEA, 2022). In addition, the vehicles achieve a long service life. The average lifespan of all vehicles in the EU in 2021 was around 12 years, (ACEA, 2023). This means that the cars can easily reach a lifetime of more than 20 years. Therefore, it is very welcome that automotive companies as BMW or Mazda are consistently developing the internal combustion engine further (Wetzel, K.; et al., 2023), (Schäfer, P, 2023).

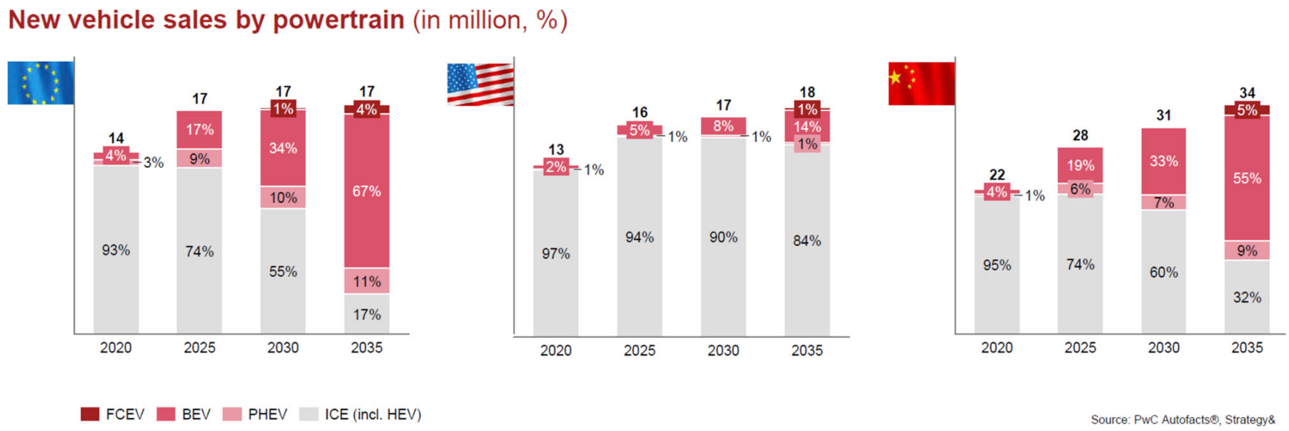


Figure 8. Forecast market distribution of new sales in EU, USA, China by drive type (PWC, 2021)

Further development and improvement of the ICE is essential for the future. Even in 2040, a large number of new vehicles with ICE or electrified internal combustion engines (HEV, PHEV) will enter the world markets. Figure 8 illustrates this very clearly for the EU, US and Chinese markets. In addition to the further development of the ICE, and taking into account its long service life, it is clear that the use of alternative fuels is an important way of reducing CO_2 emissions from the global passenger car fleet even by 2035.

4. REGENERATIVE FUELS AND BATTERY ELECTRIC VEHICLES.

Of course, BEVs have the best possible efficiency. This is because of the energy status of electricity compared to caloric energy. The electricity stored in the batteries is powerful secondary energy, or "pure exergy". If the electricity comes from wind, hydro or photovoltaic power plants and goes directly into the batteries, BEVs have a high level of efficiency. The situation changes if the electricity comes from gas, coal or oil-fired power stations. In addition to efficiency, another important factor is energy storage. Electrical energy cannot be stored in large quantities because of the limited capacity of batteries. This is critical because wind, hydro and solar power are highly volatile. There must be a way to store and transport renewable energy in large quantities. One answer is to convert electricity into gaseous energy (Power to Gas PtG: hydrogen or methane) or liquid energy (Power to Liquid PtL: synthetic fuels or e-fuels). Figure 9 shows the losses caused by the use of PtG in FC (fuel cells) or PtL in ICE drives. The losses shown in Figure 9 are the price of storing and transporting electrical energy.

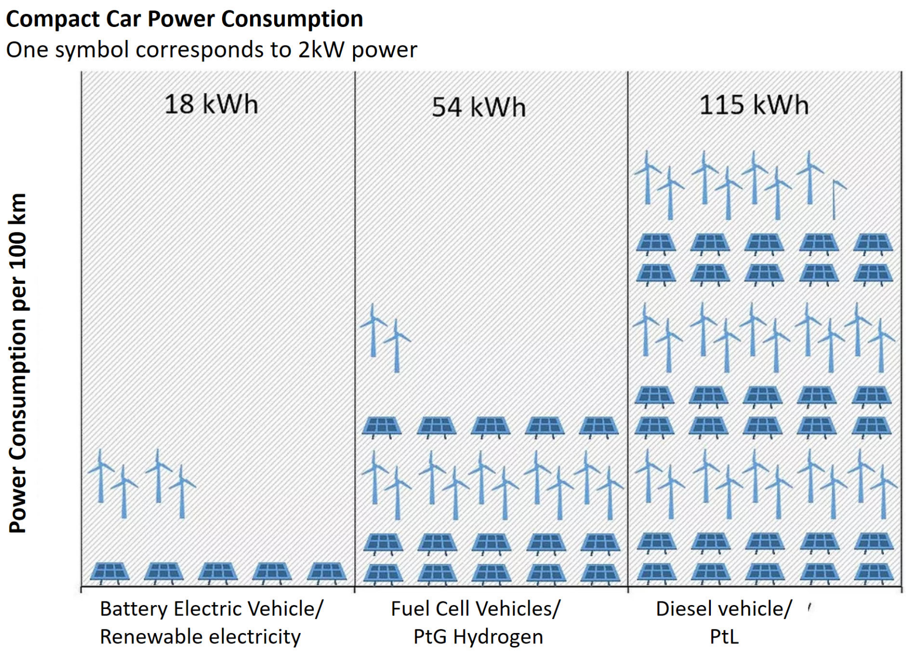


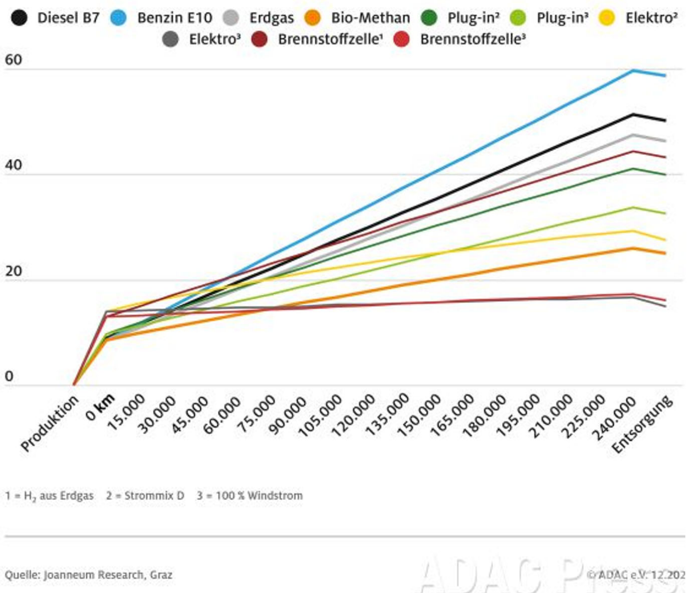
Figure 9. Energy consumption for a car journey of 100 km depending on the energy conversion system, Original illustration in German (BMU, 2023) translated into English

PtG and PtL is a way of converting electricity into easily storable energy. These processes are at the beginning of industrial mass production and belong to the 2nd generation biofuels. Porsche's ambitious goals in Patagonia in Chile are an example of this technology, see Figure 10. The vision is to produce 11.4 million litres of synthetic petrol per day by 2030 (Winterhagen, J., 2023).

In addition to the PtL and PtG strategy, there are developments to convert biomass into gases (BtG) or liquids (BtL). These fuels are also 2nd generation energies that use biomass instead of green electricity. BtG or BtL fuels will use the whole plant and not just the fat and sugar content of the plant, as it is the case with current 1st -generation biofuels.

Figure 10. Left: HIF pilot plant in cooperation with Porsche AG. Right: Board members Barbara Frenkel and Michael Steiner filling up a Porsche with e-fuel (Porsche, 2023)

In the meantime, the regenerative fuels of the 1st generation are used on a large industrial scale. Vegetable fats or fat waste is hydrogenated or is trans esterified and turned into bio diesel (HVO, FAME) or bio kerosene (SAF). Another process is the fermentation and distillation of plants. Brazil is very successful in producing ethanol from sugar cane. Every day, the country fabricates 65 million litres of crude oil equivalent.



Explanation of the drive systems shown in the diagram :

Diesel B7:	Diesel fuel containing up to 7% biodiesel.
E10 petrol:	Petrol containing up to 10% bioethanol.
Erdgas:	Natural gas
Bio-Methan:	Biomethane
Plug-in 2:	PHEV using current energy mix of German power plants (conventional and green)
Plug-in 3:	PHEV powered by 100% wind energy
Elektro 2:	BEV using current energy mix of German power plants (conventional and green)
Elektro 3:	BEV powered by 100% wind energy
Brennstoffzelle 1:	Fuel cell powered by fossil hydrogen
Brennstoffzelle 3:	Fuel cell powered by hydrogen from wind energy

Figure 11. Greenhouse gas emissions (CO2 equivalent in metric tons) of current powertrains based on a Golf model, calculated over the vehicle life cycle. ADAC study from December 2022 (ADAC, 2023)

Just looking at the emissions of the vehicles, but not at the emissions from their production, is not enough. Figure 11 shows the calculated CO_2 equivalent for both, the production and the operation, of a typical medium-sized vehicle in Europe. Biomethane ICE cars perform better than BEVs powered by the current German electricity mix of conventional and renewable power plants. The CO_2-intensive production of BEVs, especially the battery, must be taken into account, even if the BEV is powered by 100% renewable electricity: In this case, the break-even point for BEVs is around 75,000 km compared to a methane-fuelled ICE car, Figure 11.

(Koç, H, 2015) arrives at a similar analysis, calculating a break-even point of a Golf 7 TDI (mid-size car with diesel engine) compared to an e-Golf (mid-size car with battery electric drive) at around 90,000 km. However, the CO_2-intensive production of the batteries and the current electricity mix are key to the calculations.

The cost of BEVs is also a key purchasing factor, in addition to their environmental credentials. BEV sales figures have been increasing in Germany over the years, Figure 12. The influence of the reduced government subsidies for BEVs can also be seen in Figure 12 for the months of January 2023 and September 2023. This is an indication of the potentially high impact of costs.

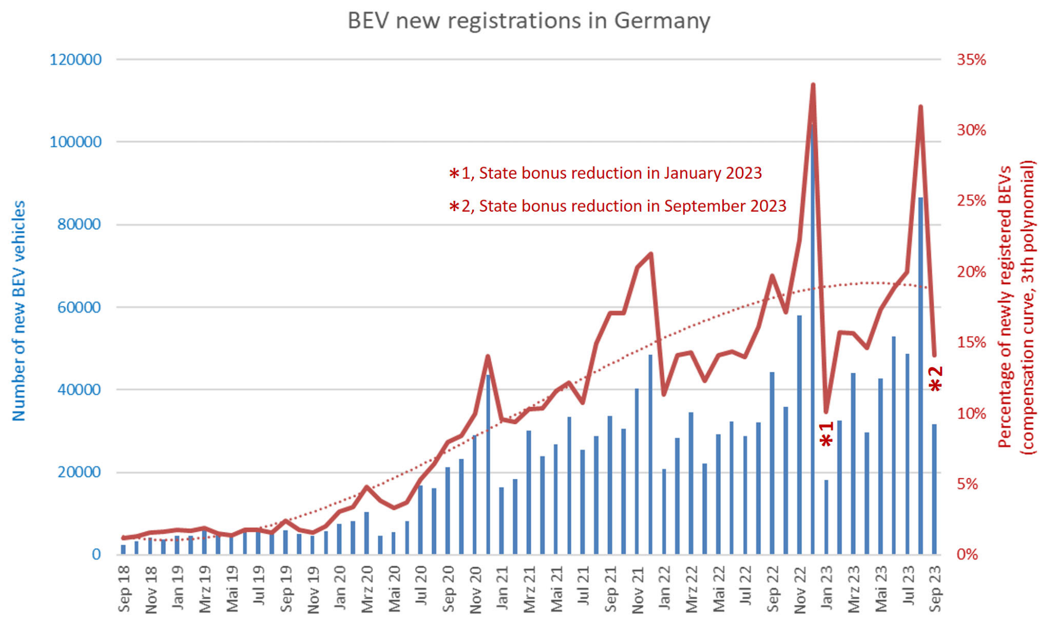


Figure 12. Influence of state subsidies on BEV registration numbers using the example of the German market. Graphical data taken from (KBA 10/2023)

5. INDIVIDUAL PROJECTS AND EYE-CATCHERS

With all drive-systems, there are always individual projects that usually serve demonstration or advertising purposes. These special forms of drives can offer a glimpse or inspiration of the future. Instead of individual projects, there are also small series existing. The two-seat Tesla Roadstar in 2008 is an example of a limited lot production vehicle that transformed the market.

Interesting special projects are currently published in shipping. An example is the nuclear-powered general-purpose ship "Thor" by the Norwegian company Ulstein, Figure 13. The 148m-long vessel is emission-free and uses a thorium liquid reactor for self-propulsion. It can also be used as a CO_2-free mobile power plant. Other companies and research institutes are also working on molten salt reactors, such as BILL GATES with the small power plant "Terra Power". China is also planning a pilot plant with molten salt reactors for 2024.

Figure 13. The visionary ship "Thor" is powered by a thorium salt reactor, runs emission-free and works as a floating power plant or as a research station (Ulstein, 2023).

In addition to these futuristic projects, there are interesting present one-off projects. One example is the battery ferry between Rodby in Denmark and Puttgarden in Germany. From 2024, the battery ferry will cover the 18.5 km route 12 times a day (Heumer, W., 2023). The new vessel is fuel-flexible because, in addition to battery operation, there are diesel generators on board to charge the batteries with electricity from Diesel fuels.

6. CONCLUSIONS AND OUTLOOK

Today's ships and those on order run almost exclusively on fossil fuels. The service life of these ships is well over 20 years (Hapag-Lloyd, 2023), so that they will need fuel for many decades in the future. Aircrafts are using fossil fuels either and the share of bio gasolines is currently marginal. The substitution by SAF fuel is just beginning. Like ships, aircraft have long life expectancies. In the case of passenger cars, there are signs of increased sales of BEVs. However, this trend is strongly influenced by the region of the world. Even in 2035, there will still be significant new registrations of ICE or HEV vehicles that have a long lifetime ahead of them. That is why the research and large-scale series production of alternative fuels is important. Further development of the ICE is also essential.

On the other hand, the efficiency and CO_2 emissions of BEVs are unsurpassed if they are not charged by e.g. coal-fired power plants. The problem, however, is the storage of large amounts of renewable electrical energy. Synthetically produced gases and liquid fuels (PtG and PtL) are a possibility. These forms of energy have a low overall efficiency, but can also supply existing vehicles, ships and aircraft. The fuel is also easy to transport. Biofuels of the 1st generation (biodiesel, bio kerosene, alcohol petrol) are of great importance today and tomorrow. 2nd generation fuels such as PtG and PtL will also become more common in the future, but their large-scale industrial production is only just beginning.

New technologies are often more expensive than conventional ones. That is why BEVs are subsidised by the government, depending on the region. In Germany, government subsidies have an impact on the sales of BEVs. In the long term, however, successful technologies should be able to survive without subsidies. The great success of bioethanol in Brazil, even without major government support programmes, is an example of this.

7. REFERENCE LIST.

ABB: Electric Vehicle Battery Supply Chain Analysis. How Battery Demand and Production are Reshaping the Automotive Industry. ABB Group. Ultima Media Ltd. March 2021, p. 14

ACEA: The Automobile Industry - Pocket Guide. ACEA European Automobile Manufacturers' Association. September 2022, p. 44

ACEA: Vehicle in Use. ACEA European Automobile Manufacturers' Association. Passanger cars by age. JANUARY 2023, p. 10

ADAC: Elektroauto wird immer besser. Allgemeiner Deutscher Automobil-Club e.V. URL: https://presse.adac.de/meldungen/adac-ev/technik/elektroauto-wird-immer-besser.html, downloads on 09.07.2023

ANFAVEA: URL: Associação Nacional dos Fabricantes de Veículos Automotores. https://anfavea.com.br/site/carta-da-anfavea 06.01.2023

BGR: Daten und Entwicklungen der deutschen und globalen Energieversorgung. Bundesanstalt für Geowissenschaften und Rohstoffe. Hannover 2022

BMDV: Verkehr in Zahlen 2021/2022. Deutsches Bundesministerium für Verkehr und digitale Infrastruktur. Berlin Germany September 2021, p. 308

BMU: Deutsches Umweltbundesamt. URL: https://www.umweltbundesamt.de/themen/verkehr/kraftstoffe-antriebe/wasserstoff-im-verkehr -haeufig-gestellte-fragen#effizienz. downloads on 05.07.2023

BP: Statistical Review of World Energy 2022 | 71st edition. The Statistical Review of World Energy analyses data on world energy markets from the prior year.BP p.l.c., Whitehouse Associates, London 2022, p. 49

DNV: Maritime Forecast to 2050. When Trust Matters. Energy Transition Outlook 2022. DNV AS. Høvik, Norway, p. 34

European Parliament: Fit for 55: Parliament and Council reach deal on greener aviation fuels. new release. URL: https://www.europarl.europa.eu/news/de/press-room/20230424IPR82023/fit-for-55-parliament-and-council-reach-deal-on-greener-aviation-fuels. downloads on 04.07.2023, p.4

Hapag-Lloyd: Geschäftsbericht 2022. Hapag-Lloyd Konzernkommunikation Silvester Group. Hamburg Deutschland. Mai 2023, p. 162

Hartbrich, I.: Es kann keinen anderen Weg geben. VDI Nachrichten. Technical Newspaper. Düsseldorf Germany. 03th of December 2021

Heumer, W.: Mit Batteriestrom über den Belt. VDI Nachrichten. VDI Verlag Düsseldorf. Technical Newspaper. Düsseldorf Germany. 06.03.2023

IEA: World Energy Outlook 2022. International Energy Agency. IEA Publications. Revised version, November 2022, Paris, p. 235

KBA: Deutsches Kraftfahrtbundesamt. Mai 2022. Zitiert nach de.statista.com: URL https://de.statista.com/statistik/daten/studie/12944/umfrage/entwicklung-des-leergewichts-vonneuwagen. abgerufen am 19.1.2023

KBA: Deutsches Kraftfahrtbundesamt. URL:https://www.kba.de/DE/Statistik/Fahrzeuge/ Neuzulassungen/MonatlicheNeuzulassungen. downloads on 09.07.2023

KBA: Deutsches Kraftfahrtbundesamt. URL:https://www.kba.de/DE/Statistik/Fahrzeuge/ Neuzulassungen/MonatlicheNeuzulassungen. downloads on 16.10.2023

Koç, H.: Analyse der Herstellkosten und der Schadstoffemission bei der Herstellung von Fahrzeugen mit Elektroantrieb seit 1885. Bachelor Thesis. BHT Berlin, March 2015, p. 68

Porsche AG: eFuels-Pilotanlage in Chile offiziell eröffnet. Porsche newsroom. URL: https://newsroom.porsche.com /de/2022/unternehmen/porsche-highly- innovative-fuels-hif-eroeffnung-efuels- pilotanlage-haru-oni-chile-synthetische-kraftstoffe-30730.html, downloads on 09.07.2023

PWC: Digital Auto Report 2020 - Navigating through a post-pandemic world. PwC Strategy& GmbH. Düsseldorf Germany 2021, p. 11

Rockenstein, S.: Hybrid für Schiffe. MTU / Rolls-Royce Power Systems AG. URL: https://www.mtu-solutions.com/eu/de/stories/marine/smm-2018/hybrid-fuer-schiffe.html, downloads on 30.06.2023

Schäfer, P.: Mazda bringt PHEV-Modell mit Kreiskolbenmotor-Range-Extender. Springer Verlag Professional. URL: https://www.springerprofessional.de/range-extender/batterie/mazda-bringt-phev-modell-mit-kreiskolbenmotor-range-extender/23923972, downloads on 01.07.2023

Spiegel: Flugzeuge müssen künftig Biosprit oder E-Fuels tanken. URL: https://www.spiegel.de/auto/saf-eu-beschliesst-quote-fuer-bio-kerosin-oder-e-fuels-in-der-luftfahrt-a-f93823c0-0236-4cf6-8e10-c026cd3a6b60. downloads on 08.07.2023

Ulstein: Ship design concept from Ulstein can solve the zero emission challenge. Ulstein Group ASA. Norway. URL: https://ulstein.com/news/ulstein-thor-zero-emission-concept. Downloads on 10.07.2023

Wetzel, M.; Karl, M.; Sailer, T.; Schmid, H.: Die weiterentwickelte Efficient-Dynamis-Motorfamilie. Motortechnische Zeitschrift. Springer Verlag Wiesbaden Germany. MTZ 06/2023

Winterhagen, J.: Sprit aus Luft und Wind. VDI Nachrichten. VDI Verlag Düsseldorf. Technical Newspaper. Düsseldorf Germany. 17.06.2022

Witt, F.: DVZ Deutsche Verkehrs-Zeitung. Um bis zu 80 Prozent werden die Emissionen in der Luftfahrt durch SAF gesenkt. DVV Media Group. Hamburg. 03.05.2022