What is the environmental impact of electric cars?

ECOS, EEB, DUH information paper

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Introduction

In order to limit global warming to 1.5°C if possible, the European Union must become climate neutral by 2039. To achieve this, European Climate Law must be massively improved.[1] But the transport sector is far from complying with the existing plan "Fit for 55".[2] To achieve this, annual carbon dioxide (CO_2) emissions must fall from the current level of around 682 million tonnes of CO_2 equivalents (CO_2e) from total road transportation to 68 million tonnes of CO_2 e by 2050.[3,4] In Germany, transport accounts for around one-fifth of total emissions. Added to this are lung damage and respiratory problems caused by excessive particulate pollution. Assuming that there is no threshold below which air pollution has no effect on health, premature deaths in Germany can be estimated at 63,000 due to particulate matter and 27,700 due to nitrogen dioxide (NO_2).[5]

Therefore, a transition to a climate-friendly transport sector is urgently needed. For this, a comprehensive expansion pedestrian traffic and cycling as well as local public transport is essential. The number of cars on the roads and the kilometres driven by them must be significantly reduced.[6,7,8] The remaining unavoidable cars must become smaller, lighter, more efficient and climate-neutral. This can only be achieved through a consistent shift to all-electric vehicles. Hybrid vehicles, hydrogen drive, agrofuels and e-fuels are not environmentally friendly alternatives.[9,10,11,12]

When considering all environmental impacts, electric cars are the most environmentally compatible compared to other passenger car drive types. Despite this, replacing the approximately 246 million combustion-powered passenger cars in Europe[13] with electric cars would be completely misguided. This is because their production also involves a considerable consumption of resources and energy, and their use is accompanied by an enormous demand for land and infrastructure. In a direct comparison with other types of car drive, however, the battery drive is the most efficient and environmentally compatible option. For example, newly registered electric cars in Europe currently emit an average of 75 grams (g) CO_2 e/km over their entire life cycle, which is around 69% less greenhouse gases than comparable petrol-driven vehicles.[14] If green electricity is used during production and operation, CO_2 emissions are reduced even further. The resource consumption of the two drives can be classified as high in each case. The battery drive requires a large proportion of abiotic resources (minerals and metals) in its production phase. The combustion engine consumes a great amount of biotic resources, such as gasoline and diesel, during the use phase, which cannot be recycled after a single use.

In order to fully reduce the environmental footprint of electromobility, renewable energies must be expanded at an accelerated pace, efficiency standards for passenger cars must be introduced and environmentally compatible extraction and recycling of resources must be ensured.

Further information and policy recommendations on batteries can be found here:
https://www.duh.de/projekte/batterien/

Further information and political recommendations for action on the mobility transition can be found here:
https://www.duh.de/themen/verkehr/

	Combustion drive	Battery drive
Drive	Combustion engine with exhaust gas purification unit (catalytic converter)	Electric motor with battery
Fuel	Fossil petrol/diesel, biogenic petrol/ diesel, e-fuels	Electric current
Raw materials car	Iron, aluminium, plastic, magnesium, copper, plastic, glass, rubber and others[15,16]	
Material footprint	16 tons[17]	42 tons[17]
Raw materials drive	**Internal combustion engine:** iron, aluminium, copper, rubber, plastic and other[18] **Catalyst:** platinum, palladium, rhodium and other[19] **Starter battery:** lead, sulphuric acid, polypropylene and others[18]	**Asynchronous motor:** copper, aluminium, iron[20,21] / **Permanent magnet motor:** copper, iron, aluminium, dysprosium, neodymium and others [22,21,16] **Drive battery NMC:** nickel, manganese, cobalt, lithium, copper, aluminium, graphite and other[23] / **LFP:** lithium, iron, phosphorus and other[24] **Starter battery:** lithium, iron, phosphorus and other[25]
Efficiency **From energy source to wheels**	24 % (diesel fossil)[26] 20 % (petrol fossil)[27] 15 % (e-fuels/electricity)[27,28]	64 - 77 % (green electricity)[27,26,29,30] 45 % (electricity mix)[26]
Direct emissions when driving	Carbon dioxide (CO_2), nitrogen oxides (NOx), sulphur oxides (SOx), particulate matter (PM), microplastics[31]	Fine dust and microplastics (from tyre and brake abrasion)
CO_2 emissions over the entire life cycle	200 - 250 g/km[14,16,32,33] (petrol/ diesel fossil)	75 - 150 g/km[16,26,32,34] (electricity mix)

Table 1 Comparison of battery and combustion drive systems

Summary

- » Only a comprehensive mobility turnaround with significantly fewer cars and a switch to walking, cycling and public transport will enable climate-friendly and environmentally sound mobility. These things should be prioritised by politicians and not the 1:1 replacement of conventional cars with electric cars.

- » Passenger cars with combustion and battery drive are both environmentally intensive forms of drive and should be avoided if possible. In a direct comparison, the battery drive is less harmful to the environment than the internal combustion engine.

- » In life cycle assessments, the battery drive performs worse in the consumption of minerals and metals and the combustion drive in energy consumption, global warming and ozone precursors. By 2050, it is assumed that battery drive will have a significantly lower environmental impact than combustion drive in almost all areas.

- » With 75 - 150 g CO_2 e/km (electricity mix), the battery drive has significantly lower CO_2 emissions over the entire life cycle than the combustion drive with 200 - 250 g CO_2 e/km. For example, an average medium-sized diesel car of the "Golf class" causes about three times as much CO_2 e/km as a comparable electric car. If renewable energy is used, the CO_2 emissions of the battery drive can be largely avoided.

- » Over the life cycle, the combustion drive consumes more water than the battery drive. Due to a higher share of green electricity and oil sources that are more difficult to tap, this difference will increase significantly in the future. Particularly problematic is the pollution of water with pollutants through crude oil extraction as well as damage to and consumption of water reservoirs in dry areas during lithium extraction. The latter can be reduced through water recovery and separation processes as well as lithium-free batteries.

- » Compared to other types of drive, the battery drive is the most efficient with an efficiency from energy source to wheels of 45 % with the current electricity mix and 64 - 77 % when using green electricity. In comparison, the combustion engine has an efficiency of only 20 - 24 %.

- » To reduce the environmental impact of electric vehicles in the future, the use of green electricity, minimizing vehicle weight, new battery types without critical raw materials, due diligence in the supply chain and efficiency requirements can be important leverages.

- » In addition, reuse and recycling can significantly improve the environmental impact of a battery. In particular, the repair as well as the reuse of traction batteries as stationary energy storage devices should be promoted more strongly politically.

- » Hydrogen drive is not an environmentally friendly option for passenger cars, partly because it is significantly less efficient than battery drive, even when renewable energies are used to produce hydrogen.

- » Agrofuels and e-fuels are not a solution from an environmental perspective, as they do not make an effective contribution to climate protection and their use is highly inefficient. Even when using green electricity for their production, e-fuels only achieve an efficiency of 15 %. When using the electricity mix, e-fuels are significantly more harmful to the climate than fossil fuels. Agrofuels also cause higher emissions than fossil fuels when land use changes are taken into account.

1. How climate-compatible are electric cars?

Life cycle assessments show that the battery drive has a significantly lower CO_2 footprint over the entire life cycle (production, use and disposal) than the combustion drive.[16,32,35] With the current EU electricity mix - i.e. a 44.6 % share of renewable energies[36] - the CO_2 emissions of an electric car are 66 - 69 % lower than those of a comparable car with a combustion engine.[14,34,37] Whereas a diesel vehicle under normal driving conditions in Europe emits up to 250 g CO_2 e/km[14,33] taking into account the entire life cycle, an electric vehicle with a battery capacity of 53 kilowatt hours (kWh) emits only 75 g CO_2 e/km.[14, 33] Thus, an average medium-sized diesel car of the "Golf class" produces about three times as much CO_2 e/km as a comparable electric car.[33]

Greenhouse gas emissions of a mid-size car with internal combustion (diesel) and battery drive (53 kWh battery capacity) over the entire life cycle.

Source: ICCT (2021)[14]

The CO_2 emissions of battery drive are currently caused primarily by battery production and electricity supply. Depending on the manufacturing process and battery type, between 40 and 350 kilograms (kg) of CO_2 emissions are produced for one kWh of battery capacity.[38] These emissions could be largely avoided if renewable energies were used for production.[16] The CO_2 emissions caused by driving are also due in particular to the use of coal and gas for electricity generation and can be reduced to 1-2 g CO_2 e/km, i.e. almost zero, by using green electricity.[16] Even if the battery is produced in China and the electric car is charged with pure coal-fired electricity, it still emits 37 % less CO_2 over its life cycle than a car with a combustion engine.[34]

Currently, vehicle weight is increasing. This trend can also be observed for battery-powered vehicles. However, this must be counteracted in the future, as the use of smaller vehicles with lower vehicle weights and material savings through smaller battery capacities has a significant impact on reducing emissions.[16,35] The increasing share of renewable energies in the electricity mix and flexible charging management, as well as the planned EU battery regulation[39], which sets maximum values for CO_2 emissions from batteries over their life cycle, will further reduce CO_2 emissions from battery drive. The rapid development of new battery types and materials will also lead to lower CO_2 emissions during production in the future. Finally, due to their high residual capacity, batteries from electromobility can be reused as stationary electricity storage units, which again significantly improves their eco-balance and means that fewer new storage batteries need to be produced.

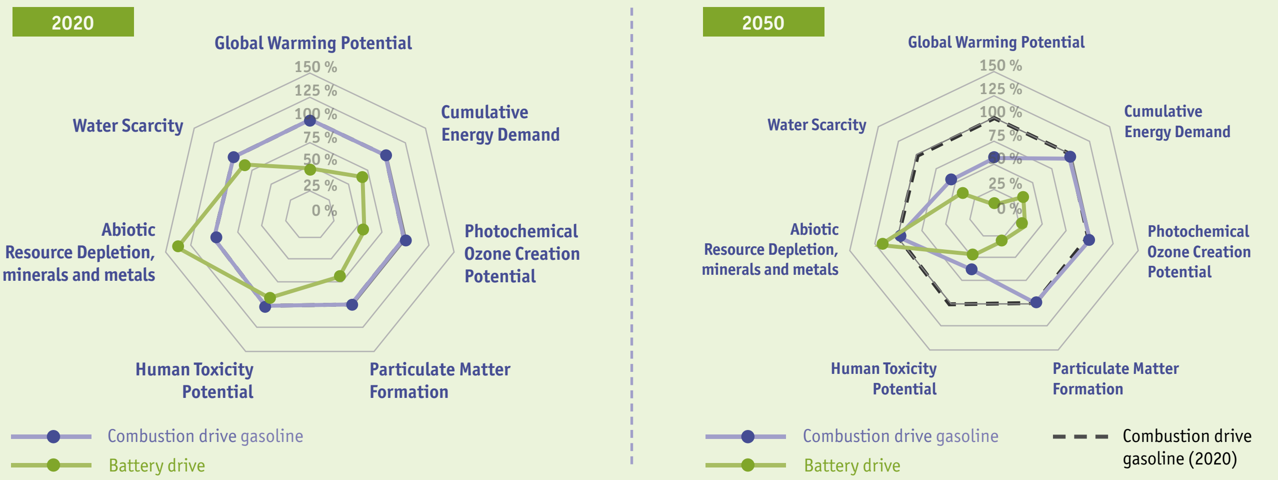
2. What is the ecological footprint of electric and petrol or diesel fueled cars?

Whether combustion or battery-powered, the production, use and disposal of every vehicle has an impact on the environment. While in the case of internal combustion engines, the main environmental impact is caused not only by production but also by use, battery production accounts for a significant proportion of the environmental impact of battery-powered vehicles. In the latter case, battery production currently accounts for about 40-50 % of greenhouse gas emissions over the entire life cycle.[38] An assessment of which type of drive is less harmful to the environment when all environmental impacts are taken into account can only be made qualitatively. A quantitative comparison - for example in the course of life cycle assessments - is an important basis for this, whereby the result is strongly influenced by different calculation methods, system limits, impact indicators, data basis and data timeliness, etc. The results of these comparisons can be used to assess the environmental impact of the different drive types.

Current life cycle assessments attribute higher environmental impacts to battery drive than to combustion drive over the entire life cycle in terms of abiotic resource consumption (minerals and metals). In contrast, the combustion engine has a worse result in terms of cumulative energy consumption, global warming and ozone precursors. Indicators such as particulate matter, acidification and toxicity are influenced by mining regions and conditions, among other factors, so results vary.[16,28,32] By 2050, the battery drive is expected to have a significantly lower environmental impact than the internal combustion engine in almost all impact categories. Although the impact of the resources needed for the battery drive is significant at the moment, the consumption of abiotic resources is expected to level off for both types of drive during this period.[28] The reasons for this are more efficient manufacturing processes and batteries, new battery types with lower demand for environmentally intensive raw materials, an increasing share of renewable energies in production and use, and improvements in the recycling of battery raw materials. In the case of combustion drive, the use of so-called alternative fuels such as e-fuels, hydrogen or agrofuels is not a sensible alternative from an environmental point of view (see chapters 5 and 6).

In an overall assessment of the current and future environmental impacts, battery drive is less harmful to the environment than combustion drive. What is needed is a drastic reduction in private transport, an earlier ban on the registration of cars with combustion engines and a massive expansion of walking, cycling and public transport.[40,41,42,43,44] In addition, the use of smaller vehicles with lower vehicle weight and smaller battery capacities has a significant effect on the reduction of emissions.[35]

Environmental impact of combustion and battery drive



Comparison of the life cycle assessment of compact passenger cars with combustion and battery drive systems from 2020 and 2050.

Source: EU COM (2020)[28]

The main reason for the high environmental impact of the battery drive in terms of abiotic resource consumption is the production of the lithium-ion battery. Here, among other things, there is water and soil pollution due to mining and the energy-intensive refinery and manufacturing processes, which cause CO_2, ammonia, sulphur and nitrogen oxide emissions. The high environmental impact of internal combustion drive in terms of energy consumption and global warming is mainly due to the production and combustion of fuels for driving and the related environmental disasters in crude oil extraction and processing (see chapter 3).[32]

In addition, combustion drive requires catalysts for exhaust gas purification, which contain platinum group metals and require environmentally intensive extraction and processing.[45]

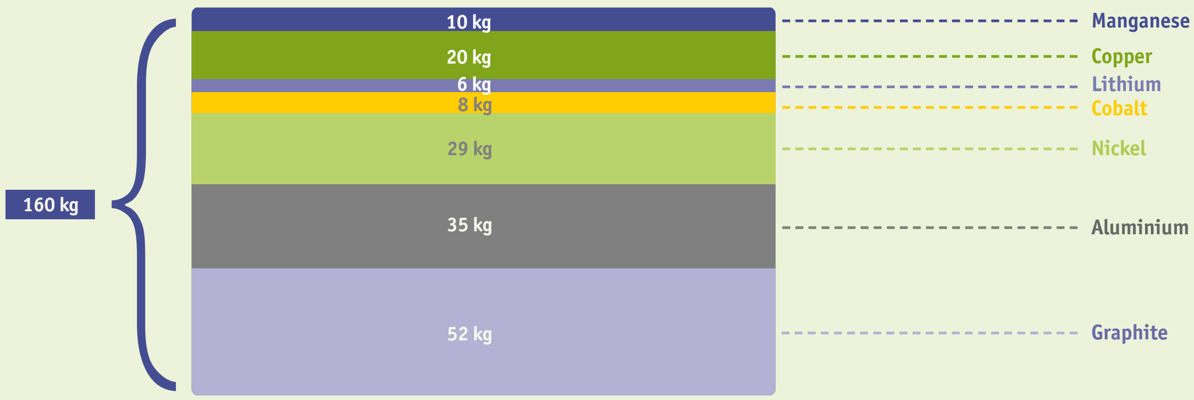
It is worth pointing out that, compared to internal combustion drive, battery drive causes virtually no direct releases of pollutants during driving, thus improving air quality in urban areas and leading to fewer respiratory-related deaths.[32,33,46] In contrast, the mining and processing of raw materials for battery, catalytic converter, engine, body, and fuels repeatedly threatens human rights and indigenous peoples (see Chapters 3 and 4).[47,48] In order to better protect environmental and human rights in the supply chain, the EU Battery Regulation[49] and the EU Supply Chain Act50, among others, are intended to introduce far-reaching transparency and liability obligations, although in some cases certain risk categories, products, raw materials and sectors as well as small and medium-sized enterprises are still exempt.

3. How resource-intensive is the battery drive?

How resource-intensive battery and combustion drive are is often the subject of controversial discussion. Although the comparison is complex and the raw materials required for both drive technologies are different, clearly both drive technologies have a high resource impact.[51] The consumption of abiotic resources (minerals and metals) is currently significantly increased for the battery drive due to battery production.

The consumption of biotic resources (e.g. petroleum) is greatly increased for the combustion drive even though the electricity for charging the battery drive is at the moment partly generated with fossil fueled power generation plants.[52,53]

Material composition of a drive battery

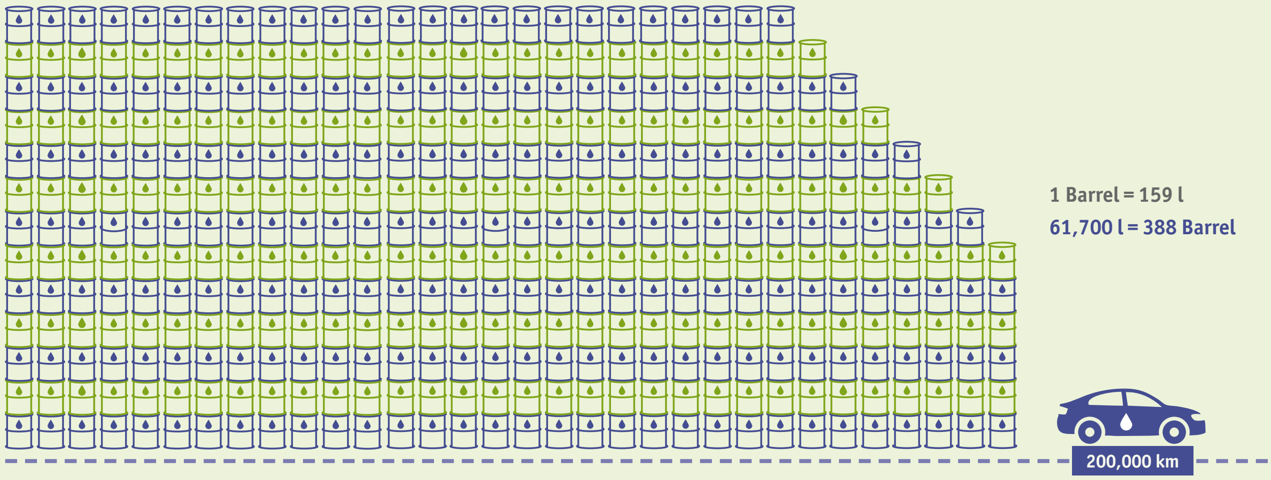


Composition of a 160 kg lithium-ion battery.

Source: T&E (2021)[23]

For example, the battery drive requires more technology metals such as lithium, cobalt, nickel and copper for the battery and rare earths if a permanent magnet motor is used.[54] The demand for these metals will continue to increase in the coming decades due to the expansion of electromobility, among other things.[55,56] This increase in demand will be accompanied by an increase of the environmental impact of mining due to harder to develop raw material deposits. On the other hand, in the future, efficiency gains will mean that fewer raw materials will be needed to produce one kWh of battery capacity.[56,57] In addition, the use of expensive and environmentally intensive raw materials such as cobalt, nickel and lithium per kWh of battery capacity has already been significantly reduced and is expected to reduce in the future.[56] To this end, low-cost battery types that do not require cobalt and nickel, such as the lithium iron phosphate battery, are increasingly gaining acceptance on the market.[58,59,60] The commercial use of sodium ion batteries for some electro mobility applications is expected by 2023. If this technology is successful, it will mean that less environmentally intensive materials will be used and lithium, cobalt and nickel will be avoided.[61,62,63] Major electric car manufacturers are already using asynchronous motors instead of the permanent magnet motor, eliminating the need for rare earths for the motor or battery.[54,64,65,66]

Crude oil consumption combustion drive during use-phase



A passenger car consumes 61,700 liters of crude oil over a distance of 200,000 km.

Source: Calculation by DUH (2022)[67]

The combustion engine requires around 61,000 litres of crude oil[67] in use alone, as well as platinum, palladium or rhodium for the catalytic converters, among other things, during production.[23,51]

The material consumption for other components such as tyres, bodywork and interior trim is roughly comparable for both drive systems.[68] By far the largest share of resource consumption in the case of internal combustion engines is accounted for by the use phase. Particularly problematic here is the environmental damage associated with oil production, such as the release of pollutants, climate emissions and destruction of natural areas, as well as severe environmental disasters at oil rigs (including Deepwater Horizon), tankers and pipelines .[69,70] In the future, it is expected that the environmental damage per barrel of crude oil will continue to increase, as oil is increasingly being extracted from sources that are more difficult to tap, such as oil sands, oil shale and the deep sea.[71,72]

In the short to medium term, the switch to battery power will result in a growing demand for metal, but less fossil fuel will be consumed.[19] While fossil fuels are no longer recyclable after combustion, metals can increasingly be recycled.[19,23,51] Thus, nickel and cobalt can be recovered through recycling with a recovery rate of over 90 %.[56] The EU Battery Regulation stipulates a minimum recycling rate of 70 % for lithium-ion batteries and 95 % for nickel and cobalt and 80 % for lithium by 2031. In addition to the recycling of battery raw materials, the reuse of traction batteries as stationary energy storage units is expected to become established, which will significantly improve resource consumption and the life cycle assessment.[73,74,75,76] This explains why the consumption of abiotic resources of the two forms of drive will converge in the future.

4. How much water does battery and combustion drive require?

Battery drive and combustion drive require water over the entire life cycle, for example for raw material extraction and processing, production, use and disposal. Water consumption can vary greatly depending on the technology used, and studies that determine the overall water demand are rare. Overall, however, the battery drive system consumes significantly less water over its life cycle than the internal combustion engine. For the production of a car with a combustion engine and a weight of 1,500 kg, for example, water consumption is estimated at 400,000 litres.[77,78] If the production of a lithium-ion battery with 64 kWh is included, the figure is around 50,000 litres more.[79] Here, the main share of water consumption is accounted for by the raw materials aluminium, lithium, nickel, manganese and cobalt, as well as for the production of the electronic components.[80]

During the use phase, an internal combustion mid-size car is estimated to consume between 170,000 and 407,000 litres of water over 200,000 km due to the water-intensive fuel supply.[81] A comparable battery-powered car is estimated to consume between 4,000 and 56,000 litres of water over the same distance assuming the German electricity mix, almost all of which is cooling water for fossil-fuel power plants.[79] When using green electricity, the water consumption of the battery drive decreases to almost zero during use.[82]

However, it is not the quantitative consumption of water that is problematic, but the environmental problems associated with the extraction of crude oil or lithium, for example, such as contamination with pollutants or salt, the lowering of the groundwater level or the warming of surface waters. Here, the local conditions and local water availability are very important.

In the case of battery drive, lithium extraction from salars in particular is sometimes associated with special problems, as the majority is extracted from lithium-containing saltwater deposits in dry areas of South America.[83,47] During the process, for example, underground saltwater is extracted, which evaporates to extract the lithium at the surface. If the saltwater level drops too much, freshwater can flow in and become contaminated due to the saltwater residues.[47] The extraction of lithium from saltwater can not only lead to freshwater conflicts among the local population groups, but can also endanger the water supply of the regional ecosystems.[47] Technologies such as water recovery through condensation of evaporated water, recirculation of the brine mixture after extraction of the lithium or membrane technologies to separate the lithium without evaporation (such as osmosis plants) could significantly reduce water consumption in lithium extraction in the future.[84] The extraction of lithium from solid rock or from seawater could also reduce water consumption in the future.[85]

In the case of combustion drive, oil production in particular, especially when using oil sands, fracking technology or submarine oil deposits, as well as the almost regular oil disasters are highly problematic for water resources.[48,86] For example, oil sands have to be extracted at great expense and processed into crude oil using a lot of water, solvents and energy. For every barrel (159 litres) of crude oil, 650 litres of toxic wastewater are produced, containing pollutants such as heavy metals.[87] These forms of water-dependent petroleum extraction from unconventional sources will increase sharply in the future.[88]

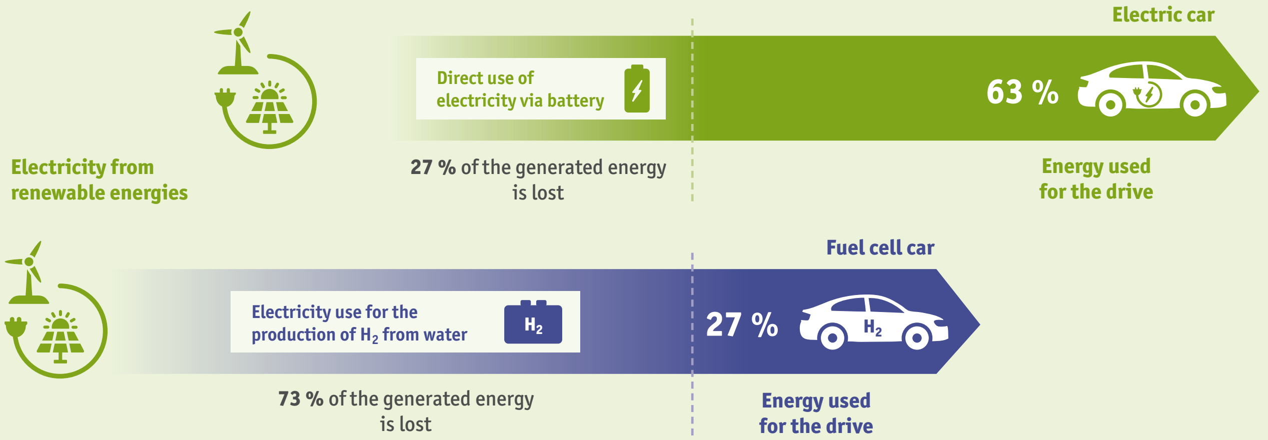
5. Is hydrogen power more environmentally friendly than battery power?

Fuel cell vehicles that run on hydrogen (H_2) cause no emissions and are therefore propagated by many stakeholders as a climate-friendly option. However, hydrogen has so far been produced almost exclusively from fossil gas, which is associated with high GHG emissions. Electrolysis is an alternative process. In this process, water (H_2O) is split into hydrogen and oxygen (O_2). The production of hydrogen via electrolysis is energy-intensive and has high energy losses during production[89,90] In addition to electricity, large quantities of treated water are needed for hydrogen production, as well as rare earths for the electrolysers and a certain amount of land for the required production facilities.[10]

Theoretically, the hydrogen produced could be used directly, but for storage and distribution it must be compressed or liquefied with additional energy input. Hydrogen can be used in fuel cells to generate electricity and drive an electric motor or can be burned in an internal combustion engine - typically after further conversion as e-fuel. The generation and use of electricity to produce hydrogen for fuel cells is associated with enormous conversion losses.[91,92] The direct use of electricity in a battery drive consumes only about half as much electricity for the same distance compared to a fuel cell vehicle powered by hydrogen.[26,37,93] Using renewable energy, a fuel cell powered car has an energy source to wheel efficiency of 35 % and a battery powered car has an efficiency of 75 %.[26,37]

Green hydrogen from renewable electricity will play a certain role in the conversion of our economy from fossil fuels to renewable energies. This is especially true for industrial processes such as in the

Efficiency: Electric cars are far ahead



Efficiency from the energy source to the wheels in battery and hydrogen drive systems using renewable energies.

Source: BMUV (2021)[27]

steel or chemical industries, as well as for the unavoidable long-distance shipping and air travel, as these require energy sources with high energy density and these areas cannot be electrified.[10,12,94,95] However, hydrogen only has an effective climate benefit if it is produced with electricity from additionally generated renewable energies and is used as purposefully and sparingly as possible. Since renewable energies and the green hydrogen produced with them are still scarce in the long term, hydrogen use should be reserved for areas where more suitable technologies are not available and should only be used as a last option after all potential for sufficiency and efficiency has been exhausted.[94] For the remaining car traffic that cannot be avoided or shifted to more environmentally friendly modes of transport, direct electricity use in the battery is by far the most efficient.[94] The partly assumed advantage of a higher range of hydro-powered vehicles has already been lost by new battery technology, or will be shortly.[96,97] Most vehicle manufacturers have therefore already largely abandoned hydrogen technology - i.e. primarily fuel cell vehicles - in the passenger car sector.[98,99]

6. Can agrofuels and e-fuels be a solution?

It is often claimed that biogenic fuels or synthetic fuels (e-fuels) can be used to operate the internal combustion engine in a climate-friendly way. In fact, neither biogenic fuels nor e-fuels can make an effective contribution to climate protection in passenger car traffic.[11,12]

Biogenic fuels are predominantly produced from specially grown food and feed crops. In order to produce even small quantities of such agrofuels, large areas of oil crops such as rapeseed, soya or oil palms (for agrodiesel) or wheat, rye, maize, sugar beet or sugar cane (for agroethanol) have to be cultivated. The use of fertile agricultural land for fuel is in direct competition with food production. The areas around the globe currently used to produce agrofuel for the German market could meet the calorie needs of up to 35 million people[100]. The use of agrofuel massively increases the demand for agricultural land and thus contributes to the global land gluttony, which leads to previously unused land - often valuable CO_2 reservoirs such as forests and moors - increasingly being converted into arable land. These land-use changes result in enormous greenhouse gas emissions, which mean that agrofuels as a whole are even more harmful to the climate than fossil fuels.[11,101,102] The intensive cultivation of farmland with the use of fertilisers and pesticides also damages ecosystems and biodiversity. Solar power generation for e-vehicles requires 97% less land for the same mileage than growing crops for agrofuels.[103]

The use of fuel from biogenic residues and waste materials is also not a scalable option for passenger car transport. Many of the intended residues can be better used as materials; a diversion of material flows to fuel production undermines the waste hierarchy (in which energy use comes last) and can cause high indirect emissions via displacement effects. The sustainably available volume potential of residual and waste materials is extremely limited. For Germany, the Federal Environmental Agency assumes that such fuels can at best cover about 1 % of the energy demand in transport, taking into account competing uses and costs.[104] This is therefore a purely niche solution.

E-fuels have similar properties to fossil petrol or diesel and can in principle be used in conventional combustion engines. For the time being, however, they are only being produced in individual pilot projects and will not be available anywhere in relevant quantities before 2030. E-fuels are by no means automatically climate-friendly and their use can even lead to high additional emissions. Their production is extremely energy-intensive and their climate impact is highly dependent on where the energy used comes from. Only on the basis of 100 % additionally generated renewable electricity is a contribution to climate protection possible. As long as the share of renewable energy in the electricity mix used does not reach at least 70 - 80 %, they are more harmful to the climate than fossil diesel.[12]

E-fuel production therefore requires huge amounts of green electricity. Due to the high energy losses and the low efficiency of the combustion engine, the efficiency when used in a combustion vehicle is only 15 % - compared to 75 % for battery power.[26,27,28,105,106] Renewable electricity, however, is the foundation of the entire energy transition; it is scarce and precious worldwide and will remain so for a long time to come. It must therefore be used in a targeted way that maximises climate benefits. Every kilowatt-hour of green electricity in direct electric applications (in the electricity sector, for e-vehicles or heat pumps) brings by far the greatest emission savings. Using precious green electricity to produce e-fuels for combustion cars instead of decarbonising the energy sector would therefore not be a relief but an additional burden for the climate.

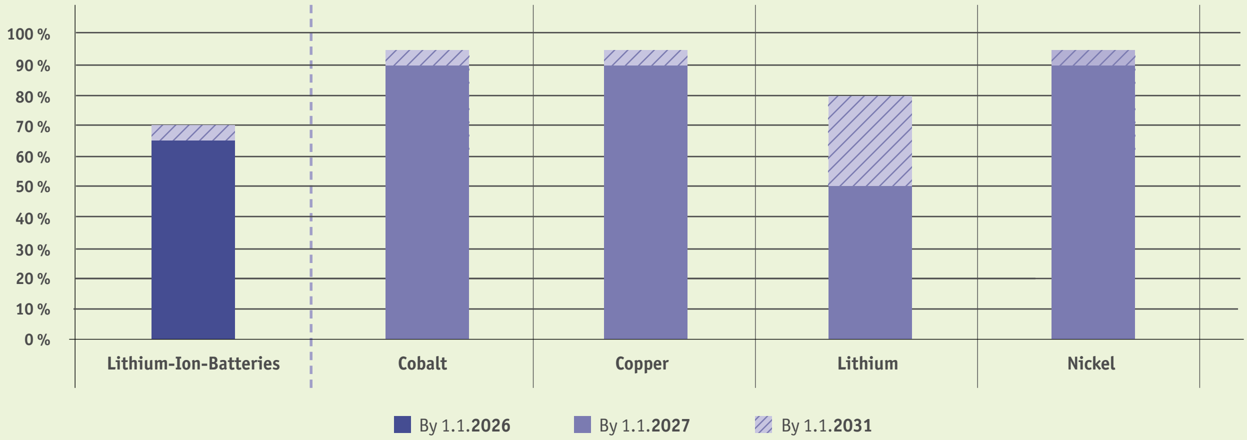
7. How can reuse and recycling make batteries more environmentally compatible?

The end-of-life phase - with good waste management - itself causes only low environmental emissions and can significantly improve the life cycle assessment of the battery drive through reuse and recycling. In this context, reuse is particularly desirable, as it means that practically no new raw materials are required and the service life of batteries is considerably extended through reprocessing and repair measures.[107,108,109] Electromobility batteries have great potential for reuse, as they still have around 70 % of their original capacity at the end of their use as traction batteries.[110] They can then be used for a further 7 to 10 years as stationary energy storage devices or for less demanding mobility applications.[23,110] Stationary energy storage is an important part of the energy transition with a strongly increasing demand.[111]

In order for a traction battery to be reused, the state of health, i.e. above all the remaining capacity, must be known and the battery management system must be able to be read out and, if necessary, modified for the new application. In addition, the battery must be easy to remove and individual components such as battery modules, electronics and housing should be available as spare parts. Software updates may also be necessary. Currently, the low market return, the many different battery types, access barriers, lack of standards and inconsistent data formats, among other things, make the reuse of traction batteries difficult or uneconomical. Some significant improvements have already been made in the EU Battery Regulation, but it is expected that the removal of further barriers will be necessary to realise the reuse potential of traction batteries.

Beyond reuse, recycling offers the opportunity to recover key raw materials such as cobalt, lithium and nickel.[112,113] Currently, most battery raw materials come from primary sources, making extraction associated with significant negative environmental impacts. However, by 2035, over one-fifth of lithium and 65% of cobalt for battery production could come from recycling.[23] The EU Battery Regulation stipulates minimum recycling rates of 80% for lithium, 95% for cobalt and nickel, and 70% for the entire battery by 2031. In addition, the mandatory battery passport with information on the material composition of the battery and minimum quotas for the share of recycled material in battery production are intended to promote recycling. A prerequisite for recycling is the proper collection of used batteries; here, individual companies are testing leasing models in which the battery is not purchased but rented.[114] New battery types with a lower proportion of high-priced raw materials will also require further research input in order to make recycling processes more economical and material-efficient in the future.[56]

Recycling targets according to the EU-Batteries Regulation



Recycling targets for lithium-ion batteries and specific lithium battery materials according to the new EU Battery Regulation.

Source: EU-Batteries Regulation (2022)[49]

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