How eco-friendly are electric cars?

A holistic view
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Are electric vehicles more eco-friendly than internal combustion vehicles?

Electric cars are seen as a way to reduce the negative environmental impact of automobile traffic. They are most frequently mentioned in the context of climate issues as a way of cutting greenhouse gas emissions caused by road traffic. Air pollution control is another context in which electric cars are discussed, due to the importance of reducing emissions of particulate matter and nitrogen oxides as major air pollutants. There are numerous publications on the environmental impact of electric vehicles, and many of these press reports and studies contradict each other. Consequently, similar questions arise again and again:

- Which information and which studies are actually reliable?
- Are electric vehicles really more eco-friendly than modern petrol and diesel vehicles?
- How does the evaluation turn out if the data is obtained from everyday
driving, rather than from information provided by the manufacturer or found in brochures?

- And how is the electric car rated if we look beyond what comes out of the vehicle’s exhaust pipe and also consider the additional emissions that occur during generating electricity and manufacturing the vehicle (especially its battery), as well as the quantity of raw materials used?

These questions can only be answered by a comprehensive life cycle analysis. This kind of analysis takes into account the whole vehicle life cycle, including the production of the individual components, the energy the vehicle needs in order to operate, the level of maintenance required and finally, its disposal. For each stage of the life cycle, consideration is also given to the environmental impact caused by the extraction and processing of raw materials and energy sources. In addition to the data provided by manufacturers, many other data sources are consulted in order to provide a meaningful, authentic evaluation that is as realistic as possible. Furthermore, the vehicle types examined need to be similar for the purpose of comparison. The aim is for the overall analysis to describe the environmental impact in gross terms.

In this brochure, the representations of the environmental impacts are based on comparing typical modern internal combustion vehicles with a typical contemporary electric car. All values given are exemplary and are based on a compact car (similar to a VW Golf).

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The most common causes of misleading or contradictory reports about the environmental impact of electric cars include comparison of different vehicle properties (for instance, segments, engine power and battery sizes), considering different sections of the life cycle (for instance, only the vehicle manufacturing process) and varying assumptions regarding the electricity mix used to produce and run the electric cars. Furthermore, outdated data are used in some cases (especially for batteries).
How high are the greenhouse gas emissions of electric cars?

The electricity mix is the main factor that determines whether an electric vehicle outperforms an internal combustion vehicle when assessing climate impact. This is because the power stations that generate the electricity do indeed emit greenhouse gases, when they are powered by fossil fuels, but electric vehicles do not produce exhaust pipe emissions when they are in operation. So running electric vehicles solely on non-renewable electricity would rather worsen the climate balance. Fortunately, more and more renewable energies are being used to generate electricity in Germany. In 2019, the share of renewable energies in the German electricity mix was already at around 42 percent, and soon, for the first time, more than half of the electricity in Germany will come from renewable sources. For this reason, electric cars powered by Germany's current electricity mix already have a significantly lower climate impact than internal combustion vehicles.
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vehicles in operation. But what about the energy-intensive production of the batteries? What impact does this have on the overall assessment?

Figure 1 shows the climate impact of a compact car powered by diesel, petrol and electricity. This analysis is based on the realistic assumptions detailed below.

The results show that the greenhouse gas emissions over the entire life cycle of a contemporary electric vehicle classified as a compact car are lower than those of comparable vehicles with internal combustion engines. Its greenhouse gas emissions are around 30 percent lower than those of a petrol vehicle and around 23 percent lower than those of a comparable diesel vehicle.
Which assumptions were used in the calculations?

1. The entire life cycle of the vehicles is taken into account. In addition to running the vehicle, the life cycle also includes the production, maintenance, disposal and recycling of the vehicle and the battery, as well as the consumption and effort for producing the electricity or fuel.

2. For vehicle manufacturing, production is assumed to take place in Europe. For battery manufacturing, the current mix of production countries is taken into account, in order to reflect the current situation. Looking ahead to 2030, it is assumed that battery production will take place in Europe.

3. The prognosis is that both electricity and fuel will have a lower climate impact in the future, due to the increasing share of renewable energy being used in both sectors. The blending of biofuels with diesel and petrol, in accordance with Germany’s national goals and requirements of the European Commission, is also taken into account.

4. It is also assumed that new vehicles tend to be used more frequently than old ones.

5. For the electricity and fuel consumption values, realistic data from the ADAC (German Automobile Association) EcoTest for typical example vehicles are used. These values are significantly higher than those stated by the manufacturers. Fleet average values are not taken into account.

6. To enable a fair comparison between different types of use, the total emissions are apportioned to an average vehicle lifetime mileage of 150,000 kilometres.
The proportion of renewable energy in the German electricity mix will continue to increase; according to the German government’s goal, it should be at least 65 percent by 2030. Improvements to battery manufacturing are also expected, in terms of both material efficiency and energy usage. If renewable energy is used during the production process, this factor alone will approximately halve the battery’s carbon footprint. For petrol and diesel vehicles, on the other hand, a comparable development for petrol and diesel vehicles is not to be expected. Although the tendency for their motors to become more efficient was taken into account, the potential of sustainable biofuels is limited. Moreover, the impact of fossil fuels may in fact worsen in the future – for example, if more fuel is extracted from tar sands or by means of fracking. Taking these assumptions into account, the comparative advantage of electric cars increases even more, to 42 percent over petrol vehicles and 37 percent over diesel vehicles.

A more detailed paper on the impact of electric cars on the climate is available on the BMU website.
Are electric cars quieter than conventional cars?

Noise is irritating and can have adverse health effects. Many people in Germany are affected by traffic noise. According to a survey by the German Environment Agency in 2018, 75 percent of the respondents felt disturbed or bothered by road traffic in their living environment. Vehicle motors are not the only cause of noise pollution from road traffic, though. It can also be caused by the movement of tyres on the road surface and, at high speeds, by aerodynamic noise. With regard to the latter factors, there is in principle no difference between an electric car and an internal combustion vehicle.

Nevertheless, there are some differences: the rolling noise of tyres is only a significant factor above a speed of 25 kilometres per hour. Below this speed, that means when driving slowly or starting to drive, the motor is the main source of noise. Electric motors are significantly quieter than internal combustion engines.
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This means that electric cars tend to be quieter on low-speed roads (in residential areas, for example) or when starting from a standstill at junctions and traffic lights. This means they do have the potential to reduce noise pollution.

However, according to EU regulations, new electric vehicles must make a noise – even at low speeds. This is mainly to alert vulnerable road users, such as people with visual impairments, to their presence. Cars must therefore be equipped with an Acoustic Vehicle Alerting System (AVAS), although the noise from these systems can be perceived as being more pleasant than motor noise. It should be noted, however, that the way sounds are perceived is very subjective; the sounds emitted by electric vehicles and specific sound designs could also be perceived as strange or irritating.

The benefits are even greater for utility vehicles such as buses, snow ploughs or refuse collection vehicles. Electric versions of such vehicles are significantly quieter – across the entire spectrum of speeds driven in urban traffic. The same applies to mopeds and motorbikes. In motorized two-wheelers, the internal combustion engine and associated processes and components are usually so noisy that electric versions are quieter at all speeds.
What are the other environmental impacts of electromobility?

Electric vehicles that are purely battery-powered have no exhaust and produce no local emissions – except for the emission of particulates caused by the rubbing of tyres and brakes and the resuspension of pollutants that were already on the ground, which happens with all vehicles. The same is true for plug-in hybrid electric vehicles (which can be plugged in and charged with electricity), at least when operating in electric mode. In places where combustion-related emissions cause air pollution that results in adverse health effects, the very absence of local emissions can significantly alleviate the problem. Nevertheless, both electric and internal combustion vehicles emit pollutants during manufacture, so the entire life cycle must be considered here as well.

Nitrogen oxides and particulate matter, which are harmful to human health and the environment, are the most problematic pollutants from vehicle traffic.
With regard to road traffic, air quality limit values are primarily exceeded in areas close to heavily used roads. This is because in these areas the local road traffic emissions are added to the background pollution from industrial and power plant emissions or from domestic heating systems and fireplaces. Local residents, pedestrians and cyclists are most affected by these emissions, but people travelling by car can also be affected by the poor air quality in the area. For this reason, it is worth beginning with a comparison of the emissions that come directly from the exhaust pipes of the various cars. Figure 2 shows that, unsurprisingly, the electric car has a clear lead in this respect, although internal combustion vehicles have improved significantly in recent years – especially in terms of particulate matter emissions. Current data suggest that nitrogen oxide emissions have finally declined, largely due to the introduction of the Euro 6d-TEMP emissions standard. The emission levels for Euro 6 a–c diesel cars were still very high.
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So how does the picture change if we also take into account the air pollutants that are emitted across the entire life cycle? If we consider not only the emissions from vehicle and battery production processes but also emissions from energy provision, the picture is different. For a start, there are nitrogen oxide and particulate matter emissions from the coal-fired power plants that supply some of the electricity for the electric vehicles. Nevertheless, coal-fired power plants use modern cleaning technologies and electric cars use only small amounts of this type of electricity, their share of these emissions is not particularly high. For electric cars, as with internal combustion vehicles, the vehicle manufacturing process has greater impact. Steel manufacturing leads to notably high levels of particulate matter emissions. Other metal products, such as those used in the batteries, are also associated with high levels of particulate matter emissions. The total emissions of these pollutants are therefore significant for all vehicle types. Without differentiating by the location of the emissions, levels are actually higher for electric vehicles than for internal combustion vehicles. For a final evaluation of the actual health risks, however, other factors are also relevant. For example, the size of the particles and how often and to what extent people are exposed to the pollutants. Manufacturing processes are often located outside densely populated inner-city areas. This means that a comprehensive evaluation of the resulting health risks must include additional considerations.

Although electric cars are already in pole position in terms of emissions that have an impact on the climate, a more differentiated picture emerges when considering particulate matter and nitrogen oxides. Mostly due to the production process, the overall particulate matter emissions from electric cars are higher. Electric cars also do not necessarily perform better in terms of nitrogen oxides emissions over their entire life cycle. Prior to 2020, Euro 6 a–c standard diesel vehicles emitted significantly more nitrogen oxides. Vehicles registered from 2020 onwards, however, meet newer emissions standards. Under these circumstances, electric cars actually emit slightly higher amounts than internal combustion vehicles. Unlike exhaust emissions, however, the largest part of manufacturing emissions occurs outside densely populated areas. Thus, electric cars still have the advantage of being locally emission-free.
What are the resource requirements of electric cars?

In addition to the noise and the emissions of pollutants that affect human health and the environment, there are often discussions about the extraction or use of scarce resources. While greenhouse gas and pollutant emissions associated with the use of raw materials are already included in the considerations discussed previously, this additional evaluation regarding resources is primarily concerned with the efficient use of finite resources in the context of sustainability. Two measures often used in resource evaluations are cumulative energy demand and cumulative raw material demand. What is the situation here for electric cars?

The cumulative energy demand for electric cars is lower than for internal combustion vehicles. This is mainly because they have highly efficient electric motors, which means that driving requires less energy.
Although there are appreciable losses of energy in the power plants powered by fossil fuels, these plants only provide a proportion of the electricity consumed by an electric car, and they also tend to be more efficient than the engines of internal combustion vehicles. This more than compensates for the higher levels of energy required in manufacturing. If the proportion of renewable energies in the energy mix continues to increase, electric cars will rank at the top in this respect, too.

By contrast, the cumulative raw material demand for today’s electric vehicles is even higher than for internal combustion vehicles. The vehicle components simply require more raw materials during the production process. Battery production in particular uses a range of materials that require intensive manufacturing processes. This leads to changes in raw material extraction and supply chains. For example, today’s lithium-ion technology calls for relevant quantities of cobalt. This is met with criticism because the supply conditions for cobalt are socially and ethically problematic and it has a high environmental impact. Furthermore, lithium-ion batteries require large quantities of copper and nickel, which also is a heavy environmental burden. Finally, lithium is also in high demand, which has consequences for the way it is extracted.

More than half of the world’s demand for lithium is supplied by Australia. The share supplied by the area in South America known as the “lithium triangle” is shrinking. For mining in that region, water consumption is of particular concern because the lithium is extracted from saltwater lakes in an ecologically important area.

Due to their high efficiency, electric vehicles are ahead in terms of total energy demand over their lifetime. In terms of total raw material consumption, vehicles with internal combustion engines are in the lead. However, there is room for improvement for electric vehicles here, especially in the area of energy storage systems. In all likelihood, continued improvements in manufacturing, material efficiency and energy storage technology will significantly improve this aspect of the evaluation.
It is little known, however, that the amount of water needed for the quantity of lithium required for an electric car battery, which lasts the vehicle's entire lifespan, is only slightly more than what is needed for about one kilogram of beef. Nevertheless, even this level of consumption can become problematic when water is scarce.

One thing is clear: with these alternative drive methods, we must make sure that the consequences are considered from the outset. For this reason, the German Federal Environment Ministry has funded the development of recycling processes for new components. Furthermore, there are already regulations for recycling batteries and vehicles. Improvements in production processes, greater material efficiency, technological innovation, recycling and using greater proportions of renewable energy in the manufacturing process may help to reduce demand for the raw materials.

A trend in this direction is already evident for batteries in electric vehicles. For example, there are now batteries that contain no cobalt at all and actually increase the electric range while reducing the overall raw material usage. It is important to keep monitoring the extent to which this trend continues and to support its continuation. Furthermore, sharpening the focus on companies’ supply chains and due diligence obligations is a promising approach to combating abuses. There is an upward trend in the number of initiatives and legislative efforts in this area, but these approaches still require a great deal of additional involvement from the players involved.

The European Circular Economy Action Plan establishes a new regulatory framework for batteries in order to promote wider participation in the aforementioned approaches. In addition to recycling, the framework also aims to work towards an eco-friendly battery production process and the sustainable procurement of raw materials.
The electric car is not the only vehicle with numerous positive environmental credentials. Fuel cell cars are also locally emission-free and climate-neutral, provided the hydrogen was produced with renewable electricity. If synthetic fuels – often referred to as e-fuels or power-to-liquid and power-to-gas – are produced using electricity generated from renewable sources, they can even make operation of diesel and petrol cars climate neutral. Nevertheless, this would not solve the air pollution control problems associated with running the cars. This section classifies the potential of these vehicle types for mitigating climate change by answering two key questions:

How much energy is required for mobility when these technologies are used?

There is a systemic disadvantage associated with e-fuels in particular: in contrast to the electric motor, using these fuels in vehicles with internal combustion engines is significantly less efficient.
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Furthermore, the production of the fuels consumes more energy than the fuel later provides as a power source. This is because several conversion steps are required to turn electricity, water and carbon dioxide into liquid fuel – and there is a significant loss of energy at each step. To a lesser extent, the same applies to hydrogen and fuel cell vehicles. Since these vehicle types use an electric motor, the drive mechanism itself is as efficient as that of an electric car. Nevertheless, the steps of generating the hydrogen and then generating electricity in the fuel cells both involve energy losses.

This means that each of these variants ultimately uses more energy than electric cars that use electricity directly. Figure 3 illustrates the differences on a 100-kilometre route. Compared to an electric car, a fuel cell vehicle requires three times as much energy and a vehicle using synthetic fuels uses up to six times as much.

**Figure 3: Electricity demand from renewable energy sources for various theoretical combinations of drive type and fuel type, per 100 kilometres, for contemporary vehicles**

<table>
<thead>
<tr>
<th>18 kilowatt hours</th>
<th>54 kilowatt hours</th>
<th>115 kilowatt hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric motor</td>
<td>Hydrogen (fuel cells)</td>
<td>Synthetic fuel (produced using renewable energy)</td>
</tr>
</tbody>
</table>

Source: Own representation using ifeu data
One might assume that this is not a problem if the electricity used is renewable. After all, vehicles produced in Germany to run on hydrogen and synthetic fuels will use the same proportion of renewable energy as battery-powered electric cars. Nevertheless, the higher energy consumption in the production and combustion of the fuel means that with every kilometer driven, the climate impact of the electricity mix derived from hard coal, lignite and natural gas is amplified. This means that even today’s fuel cell vehicles – running on hydrogen produced with German electricity – have significantly higher levels of greenhouse gas emissions over their entire lifespan than battery-powered electric vehicles and even than conventional vehicles. Furthermore, while synthetic fuels can be used in current combustion engine vehicles and do not require additional components such as batteries or fuel cells, the climate impact over the vehicle lifespan (with Germany’s electricity mix) is around three times as high than that of battery-powered electric vehicles.

What if we produced these fuels using exclusively renewable energy?

In this case, they would be climate-friendly. Nevertheless, the differences in energy requirements have an impact on costs as well as on the environment. If many new wind turbines have to be built to produce a fuel, it would be much more expensive to produce – more expensive than petrol and diesel, but also more expensive than electricity for charging batteries (see Figure 3). This is true even if it is possible to generate the renewable energy for e-fuels in very cheap locations.

It should also be taken into account that the plants for splitting water into hydrogen and oxygen (known as electrolyzers) and the plants for synthesizing fuels, have a very high demand for raw materials and resources. Moreover, even with the use of renewable e-fuels, the local environmental impact of the pollutants emitted by internal combustion engines is very similar. Although this means that synthetic fuels are less suitable for powering cars, in the future they could be necessary and useful in other areas where direct use of electricity is not possible – or if it is not possible to store the energy in a battery. One such example is the aviation sector.
In the area of road traffic, electric vehicles cannot be the only strategy for achieving the climate and environmental protection goals. A sustainable mobility turnaround will only be successful if the focus is also on avoiding car travel and shifting to other modes of transport. This also corresponds to the vision of a liveable city with an attractive public transport network, more pedestrians, more cyclists and short distances between work, home and shops and services. Nevertheless, it is likely that motorized vehicles will continue to be used for a significant proportion of journeys in the future.

It is therefore important to lessen the impact of car traffic on the climate and the environment. Electric cars can make an increasingly significant contribution to reaching this goal. This applies above all to climate protection – an area in which electric cars already have a clear lead. This lead will continue to grow as the share of renewable energies in electricity generation continues to increase. It is highly likely that today’s newly registered vehicles will still be on the roads in 2030 and that at least 65 percent of electricity will then come from renewable sources.
The picture is more differentiated for the other environmental impacts. More raw materials are used for electric cars than for conventional vehicles and more particulate matter is emitted over the entire life cycle as well. In terms of nitrogen oxide emissions, diesel vehicles in particular are now in a better position, because vehicles registered from 2020 onwards generally adhere to the legal limit values even during real life driving. Nevertheless, the actual health impact also depends on where the emissions are generated. So it matters “what comes out directly at the exhaust”. In this respect, electric vehicles continue to have an advantage in polluted urban environments because they are locally emission-free.

All in all, then, the overall assessment depends on how the various factors are weighted and balanced, and on the timescales used. Should climate protection be weighted more heavily than the use of raw materials? How should the local protection of human health be valued, as opposed to emissions outside of city centres? And what climate-friendly alternatives actually exist – if we want the car to be part of our future?
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