Electromobility: Electric cars, plug-in hybrids and batteries

In the context of greenhouse gas emissions in Germany, transport is still a problem area: while emissions from industry, buildings and agriculture fell between 1990 and 2019, emissions from the transport sector did not.

Electromobility can help resolve this pressing environmental problem. But this cannot be achieved simply by switching to electric motors. The move towards greater sustainability is unlikely to succeed without changes both in the share of motorised private transport and in the type of vehicles used – SUVs are still very much in fashion.

The electric motor is very energy-efficient, but this advantage is diminished if transport continues to be dominated by conventional motorised private transport with its low efficiency per person-kilometre. The need for raw materials for vehicle manufacture remains at the same high level.

As with many technical developments – another example from the transport sector being autonomous driving – the environmental benefit therefore depends not on whether electromobility prevails but on what form it takes. Climate-friendly mobility is not just a question of technological development. It must be accompanied by awareness of sustainable travel behaviour, and the policy framework must be designed to reward such behaviour.

The greenhouse gas balance: Electric vs combustion-engine car

However climate-friendly an electric car may be by comparison with an economical diesel one, it still contributes to the emission of greenhouse gases via the production of electricity, because most of Germany's electricity still comes from fossil sources such as coal. However, on the road an average medium-size Golf-class car that runs on diesel produces roughly three times as much CO_2-equivalent emissions as a comparable electric vehicle (EV). CO_2 equivalents (CO_2e) are a measure of the harmful global warming impact of different greenhouse gases.

Under normal road conditions, the diesel car emits more than 200 grams CO_2e per kilometre. By contrast, an electric vehicle with a battery capacity of 60 kilowatt-hours accounts for only a little over 60 grams CO_2e per kilometre in the usage phase. However, the energy-intensive manufacture of the electric car results in an additional six tonnes of greenhouse gas emissions by comparison with the production of the combustion-engine car. Assuming that a car covers 180,000 kilometres in the course of its lifetime, the emissions attributable to an electric car are lower than those of a diesel by around 25 tonnes CO_2e. This calculation is based on the German electricity mix and takes account of the fact that the proportion of renewables will increase in future.

Electromobility and green electricity go together

Electric vehicles produce no immediate exhaust greenhouse gases – locally, on the road, they are therefore carbon-free. The carbon footprint of an electric car depends ultimately on the electricity used to power it. Users of electric vehicles can contribute to the expansion of renewables, for example by using green electricity to charge the car.

However, the benefit depends on the environmental quality of the electricity. Many suppliers of green electricity and EV energy merely redistribute electricity from renewables between various electricity consumers. It is important that an actual incentive for the additional expansion of renewables is created.

Particulate matter in cities decreases

While global warming is a global problem, the damage caused by atmospheric pollutants depends to a greater extent on where they are emitted. Around 60 percent – and in some cases up to 80 percent – of nitrogen oxide emissions harmful to human health are caused by road traffic, with diesel cars being responsible for three-quarters of the total.

More electric transport in urban areas significantly improves the air quality there, for electric vehicles produce zero emissions locally because they do not release any particles from combustion processes.

The production of "secondary" particulate matter is also reduced. The remaining emissions as a result of tyre and brake abrasion and dust disturbance are somewhat less harmful to human health and environmental quality. Another advantage may arise from the fact that electric cars can brake using recuperation – in a process known as regenerative braking – which results in less wear on the brake pads. This may mean that they produce less particulate matter. However, this link is not yet substantiated sufficiently.

Battery raw materials: A sticking point or not?

Manufacturing the batteries of electric vehicles calls for large quantities of valuable metals such as lithium, nickel and cobalt. For example, a drive battery may contain between 6 and 11 kilos of lithium and between 9 and 13 kilos of cobalt. Another important raw material is copper, which is used in the vehicle's electronic systems and in the charging infrastructure. In addition, rare earths such as neodymium and dysprosium are needed for the electric motor, albeit in smaller quantities.

Within a few decades the demand for some of these raw materials will significantly exceed the amounts that are currently being produced. Scenarios predict, for example, that global demand for lithium could increase tenfold by 2050. Per year, that would still be less than one percent of the currently identified resources. Overall, there is sufficient lithium to meet demand. Shortages could arise, for instance because production, processing and recycling do not increase in line with demand or because there are only a few providers, but the bottlenecks would only be temporary.

Electromobility also saves some important resources: there is no longer any need for lead for the starter battery or for rare earths and metals from the platinum group for the catalytic converter. And, last but not least, electromobility ultimately frees us from our dependence on oil.

A recycling system is essential

There are more than a billion cars in the world, each of which contains large quantities of valuable primary and secondary resources. Established recycling systems already exist for many materials, because mass production makes commercial recycling worthwhile. Recycling rates of well over 90 percent are usual for end-of-life vehicles, at least in industrialised countries.

This not only lessens the environmental and social consequences of resource production in the mining countries: it also significantly reduces the adverse impact on the climate. The greenhouse gas emissions of recycled aluminium, for example, are 95 percent less than those of newly produced aluminium. It is likely that similar recycling loops will be created for “new” materials.

Binding requirements such as collection and recycling quotas, the formulation of environmental and social standards for primary raw materials, and standards for recycling-friendly construction could promote battery recycling and make it more attractive economically.

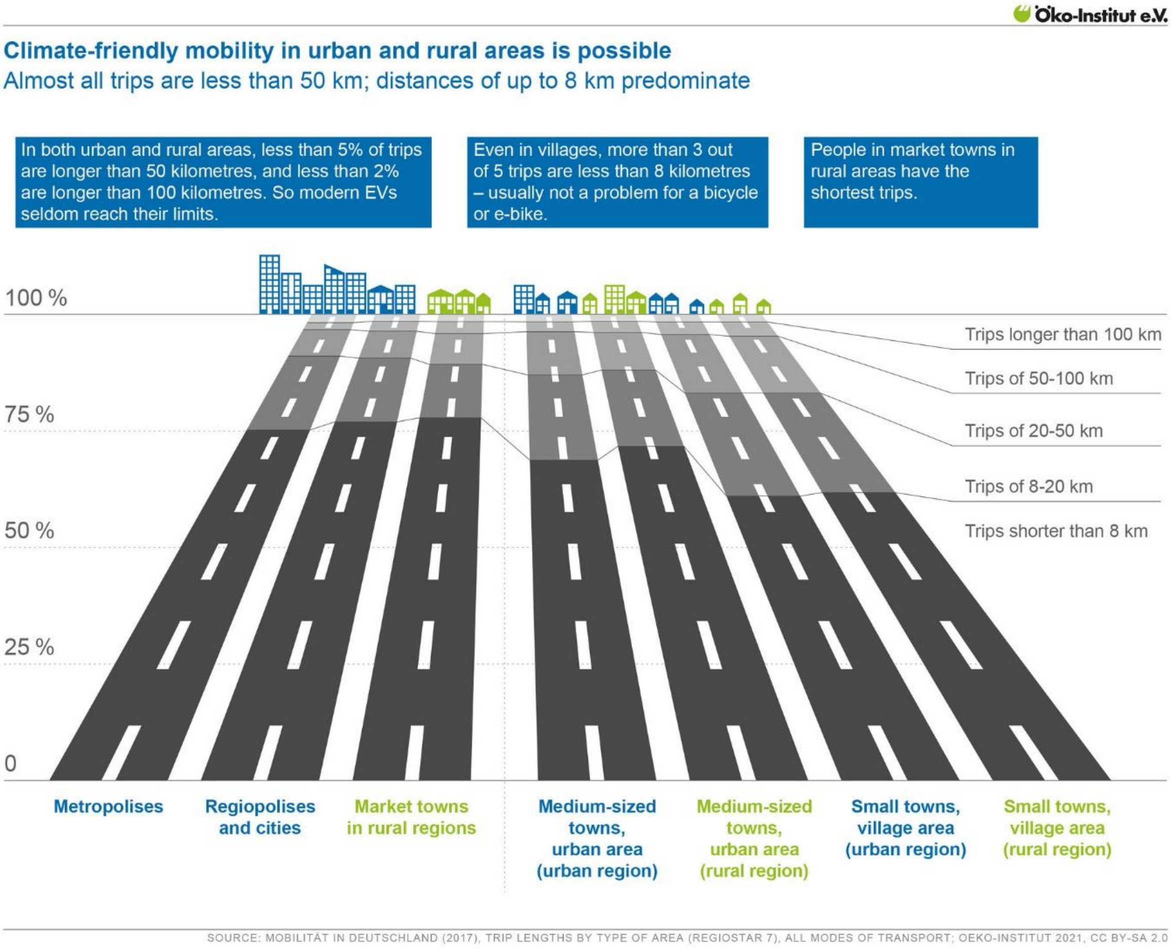
The problem of range

According to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP), almost all EVs currently on the market have a range of more than 200 kilometres. Some – especially vehicles in the middle and top classes – significantly exceed this, with WLTP ranges of between 300 and more than 500 kilometres.

Vehicles are often offered with a choice of battery sizes so that customers can choose the one that meets their needs. However, the range can be halved by the use of auxiliary systems such as heating or air conditioning, by cold external temperatures or by an inappropriate driving style.

But more than 90 percent of private cars in Germany cover distances of less than 80 kilometres per day except for occasional journeys such as holidays and long business trips. This means that in nine out of ten cases, using a battery electric car for everyday journeys presents no problem, even if no charging facilities can be accessed during the day and the batteries are therefore only charged at night.

Figure: Distances of up to eight kilometres predominate



Source: Oeko-Institut

Plug-in hybrids consume more electricity and petrol

Plug-in hybrids appear to provide the most climate-friendly solution to the range problem. A plug-in hybrid electric vehicle (PHEV) combines an electric motor and a conventional engine and can be charged from an external electricity supply. If half the distance travelled is powered electrically, the lifetime greenhouse gas emissions of a medium-size PHEV of the Golf class are one-fifth lower than those of a diesel-fuelled vehicle.

However, the carbon footprint of the plug-in hybrid is ultimately determined by the way in which it is used: the greater the distance that is covered on electric power, the more climate-friendly is the vehicle by comparison with ones powered by diesel or other engines. Plug-in hybrids usually consume somewhat more electricity and petrol than their all-electric or purely conventional counterparts. This is partly because the vehicles are heavier. PHEVs can also be criticised on the grounds that they are typically offered as heavy top-class vehicles that produce above-average emissions.

The difference between plug-in hybrids and hybrid cars

A hybrid car has a conventional combustion engine plus an electric motor and a small battery. Unlike a plug-in hybrid, which has a significantly larger battery, a hybrid car cannot be charged from an external electricity supply.

For town journeys, hybrid cars currently provide a useful and cost-effective way of reducing vehicle CO_2 emissions: when the car brakes, the braking energy is recovered by the electric motor, which then functions as a generator, and is stored in the battery. The stored energy is used when starting up or driving at low speed, or to support the combustion engine. The more frequent the need to brake and re-start, the greater the saving potential. In addition, the interaction between the electric motor and the conventional engine enables the combustion engine to operate within a favourable speed range. Depending on the vehicle type and the driving profile, a current petrol hybrid car can cut fuel consumption by up to 20 percent and thus reduce CO_2 emissions by comparison with a conventional vehicle.

The addition of the electric motor therefore improves the vehicle's energy efficiency, but the climate benefit is limited. This is because the hybrid car still takes only diesel or petrol on board, which means that it will not profit from the future expansion of renewable energy, as the electric car or plug-in hybrid will. If the vehicle manufacturing process is also taken into account, the hybrid car's climate benefit by comparison with a combustion-engine car shrinks to around ten percent, because the production of the battery and electric motor generates greenhouse gas emissions. In overall manufacture and use an electric car scores significantly better, with a climate benefit of almost 50 percent.

Integration into the energy system: Far more electricity needed

The question is, how much additional electricity from renewables will be needed for electric vehicles? The German government wants there to be between seven and ten million EVs on the country's roads in 2030. This would roughly triple the demand for electricity in the transport sector, requiring up to 30 terawatt-hours of additional electricity annually – equivalent to about five percent of German electricity consumption in 2019.

Meeting this electricity demand with solar and wind energy would involve generating 13 percent more electricity from renewables than is the case today. For comparison, electricity exports from Germany in 2019 amounted to around 33 terawatt-hours – roughly the amount needed by electric vehicles in 2030.

If the proportion of cars on the roads that are powered by electricity eventually rises to 75 percent, the additional electricity requirement would increase to between 85 and 100 terawatt-hours per year. This is a little less than the total onshore wind energy generated in Germany in 2019, which was provided by around 29,500 wind turbines. Assuming the use of modern onshore turbines, this scenario would require approximately 10,000 new wind turbines. Suitable onshore and offshore sites in Germany are in principle available. Locally, however, there are often obstacles and acceptance problems, and other new electricity consumers, such as buildings and industry, must also be considered. Economical vehicles and efficient organisation of transport systems are therefore essential.

Charging and public charging infrastructure

Home-owners who can park their car on their own land will usually have no problem installing a charging point. A simple wall-mounted charger, known as a wallbox, uses three-phase alternating current and has a maximum output of 11 kilowatts. This is much the same as the three-phase current to which a cooker is usually connected.

Alternatively, the vehicle can be charged from a single-phase wallbox or a conventional earthed socket. However, the power transfer capacity is then only 3.7 kilowatts, so charging takes longer. Private cars are usually parked for more than ten hours overnight. This charging time is long enough to fully charge standard electric vehicles. To estimate the time needed to charge the vehicle battery from 0 to 100 percent, the usable battery capacity is divided by the charging capacity.

Many providers and online communities now supply information about the public charging infrastructure with a summary of the number, capacity and facilities of charging stations and details of prices, billing systems, access, opening times and payment methods.

Costs

Without subsidies, electric vehicles are more expensive to buy than vehicles with a combustion engine. On the other hand, they are cheaper to run, mainly on account of their lower energy costs. In addition, the costs of servicing, repairs and taxation are lower. Purchasers of electric and plug-in hybrid vehicles also benefit from the “buyer’s bonus” introduced in Germany to encourage electromobility, which is paid partly by manufacturers and partly by the government.

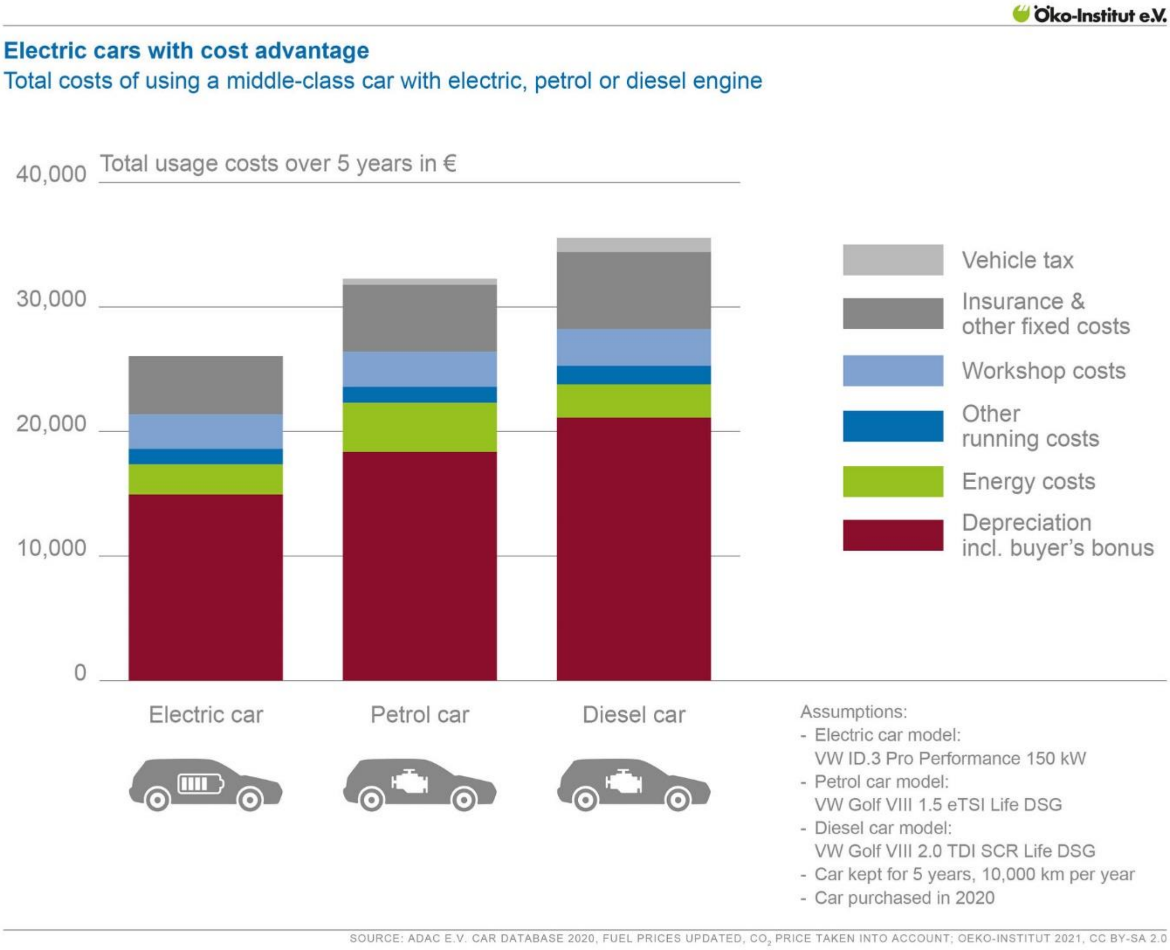
Whether an EV proves to be cheaper overall than a combustion-engine vehicle depends to a large extent on whether it benefits from the buyer’s bonus and how much it is driven. The ADAC performed a cost comparison in which it concludes that, because of the subsidy, the overall costs of electric vehicles are frequently lower than the costs of comparable combustion-engine vehicles, even when the annual distance driven is only 10,000 kilometres.

Project: Questions and answers on electromobility

“Is the overall environmental footprint of an electric car more climate-friendly than that of an economical diesel one?” These and other questions are often put to the electromobility office at the State Energy Agency (LEA) for Hesse. Answering such questions is not always straightforward, because it is often necessary to consider complex interactions between different factors and make assumptions about the future. On behalf of the LEA, the Oeko-Institut has collected and answered the most frequently asked questions. The second edition of the compendium (in German) is already available.

Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Landesentwicklung: Klimafreundlich, effizient, smart? Antworten zur Elektromobilität

Figure: **Electric cars can be cheaper**



Source: Oeko-Institut

Too often in combustion-engine mode: Plug-in hybrids jeopardise climate targets in the transport sector

In a study conducted on behalf of the German Environment Ministry, researchers from the Oeko-Institut, the Institute for Energy and Environmental Research (ifeu) and from "Transport & Environment" analysed the environmental impact of plug-in hybrids. They found that, in everyday use, plug-in hybrid vehicles tend to use the combustion engine most of the time. This means that they emit significantly more CO_2 than was previously assumed in the projections of German greenhouse gas emissions to 2030. In the current circumstances, the further market success of plug-in hybrids therefore jeopardises Germany's 2030 climate targets in the transport sector. From the point of view of environmental policy, the subsidies in the form of the buyer's bonus and tax benefits should be urgently reviewed.

Study: Plug-in hybrid electric cars: Market development, technical analysis and CO_2 emission scenarios for Germany

Further information

Online tool provided by Transport & Environment, a European organisation campaigning for sustainable transport, allowing calculation and comparison of the CO2 emissions of conventional and electric vehicles

Oeko-Institut blog pieces in the electromobility category

Platforms that provide information on the charging infrastructure:

- Lemnet
- Going electric
- Open-chargemap
- ADAC route planner for electric vehicles
- "E-Tankstellen Finder" charging point finder
- "Mehr-Tanken" app

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