The road ahead for electric vehicles

Michael Schneider, ICCG Visiting Scholar

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Abstract

Electric vehicles are gaining traction in light of recent announcements to ban petrol and diesel car sales in France and the United Kingdom by 2040. Despite continuously growing numbers of electric vehicles sold and in total on the world's roads, their share remains as of now negligible. However, this is forecast to change over the next few decades. Electric vehicles might reach competitiveness with internal combustion engine cars as soon as in the 2020s. The electric car statistics are expected to further improve with significant shares of car sales and a millionfold car fleet in 2030. Nevertheless, a variety of challenges remains to be tackled. This includes for example the development of an adequate charging infrastructure and addressing environmental and ethical issues in the production of minerals that serve as basic components of electric cars. Out of a climate perspective, compliance with the goals of the Paris Agreement requires even more expeditious action than currently predicted. Thereby, a major prerequisite for the reduction of the carbon footprint in the transport sector through the electrification of cars is the decarbonisation of the electricity sector proceeds – electric vehicles are only as clean as their power source.

Introduction: Signs of an upheaval in the transport sector

The car industry is in turmoil. The next few decades could be disruptive, changing the individual mode of transportation more than during the whole last century.[1] This is illustrated by some recent announcements. First, carmaker Volvo has declared in the beginning of July that from 2019 on every new car model will have an electric engine, i.e. solely electric cars, plug-in hybrid cars and mild hybrid cars.[2] In its official press release, Volvo denoted this move as representing no less than the "historic end" of conventional cars.[3] Second, both France and the United Kingdom (UK) announced that they will ban the sale of cars fuelled with petrol and diesel by 2040.[4] Although the motivation in case of the UK was rather to improve local air quality, the decisions have major implications for climate change. Many consider electric vehicles[5] as a green solution that will make a major contribution to the decarbonisation of the transport sector. But what is actually required in the transport sector for embarking on a trajectory in line with the targets of the Paris Agreement to limit global average temperature rise to well below 2°C or even 1.5°C compared to pre-industrial levels? What is the current state with respect to electric vehicles? How many electrified cars are already driving on the world's streets? Which countries are pioneers in this relation and for what reasons? How is the outlook for electric vehicles? What are countries planning in this respect and how does this correspond to the strategies of major carmakers? And finally yet importantly, what are the major challenges for the proliferation of electric vehicles? Are the climate targets achievable by pinning hopes solely on the electrification of road transport? These are the leading research questions of the existing Reflection.

Climate imperative: What does the Paris Agreement require to happen in the transport sector?

The Paris climate accord set out the target of limiting global average temperature rise to well below 2°C or even 1.5°C. For this purpose, a balance between emissions and sinks of greenhouse gases (GHGs) shall be achieved in the second half of this century.[6] According to research, meeting these targets requires a decarbonisation of the global energy system by around mid-century.[7] This includes the transport sector, which has thus to be decarbonised as well. But what does this actually imply? And what are the starting conditions in the sector?

According to the IPCC, the transport sector accounted for 14 percent of global GHG emissions in 2010[8]. These emissions are largely linked to the combustion of petrol and diesel, as 95 percent of the energy used in the transport sector comes from these fuels.[9] In order to reduce GHG emissions of transportation, several alternatives are at disposal. First, transportation routes can be avoided by modern communication technologies, better efficiency of distribution networks or simply because they are unnecessary. Second, modal shifts can be promoted to reduce emissions by incentivising public transportation, cycling and walking. Finally, the third alternative is to improve the fuel and carbon efficiency of vehicles. Progress with respect to the first two options has been quite limited so far, which is why the third has gained traction. However, efficiency improvements will not be sufficient to satisfy the Paris Agreement targets, as they cannot provide for a complete decarbonisation. Therefore, the diffusion of zero-emission vehicles has come to the fore.[10]

According to studies of the Climate Action Tracker, half of all passenger cars would need to be

[1] Landberg, 2016.
[2] In a mild hybrid car, the battery is charged by the internal combustion engine by using the kinetic energy of the car, leading to a higher efficiency. This means that a mild hybrid car is still fuelled solely by petrol or diesel.
[3] Volvo Car Group, 2017.
[4] Ministère de la Transition Écologique et Solidaire, 2017; Department for Environment, Food & Rural Affairs and Department of Transport, 2017.
[5] The terms 'electric vehicles' or 'electric cars' as used in the following include both hybrid and fully electric cars.
[6] UNFCCC, 2015.
[7] Rogelj et al., 2015.
[8] IPCC, 2014.
[9] EPA, 2017.
[10] Sterl et al., 2017.

electrified by 2050 in order to be compatible with the below 2°C target. In case of the 1.5°C target, action would have to be accelerated: In this case, almost all new vehicles should cause no GHG emissions in 2050. As the average lifetime of a car is around 15 years, the sale of cars with an internal combustion engine would have to be ceased by 2035. In addition, strong modal shifts must take place for adherence to the 1.5°C target as well as a reduction of the emissions from the freight transport. Further, the 1.5°C target implies that there should be already a share of 25 percent of zero-emission vehicles in 2020 and a share of 50 percent in 2030.[11]

In order to be able to judge these numbers and prerequisites, it is important to have the current state of electric vehicles in mind. This will be considered in the next section.

The current state of electric vehicles: Large growth but still negligible share

The Global EV Outlook 2017 of the International Energy Agency provides an overview of the current state of electric vehicles. Accordingly, sales numbers of electric vehicles have reached a new record in 2016 with over 750,000 sold cars worldwide. As a result, the total number of electric vehicles has exceeded two millions in 2016 – only after in 2015 the one million-boundary had been crossed (see Figure 1). However, the two million-car fleet corresponds to a mere share of 0.2 percent of the more than one billion passenger cars in total. In addition, the growth rate of electric vehicles has decreased in the past years: In 2014, the rate was still at 84 percent, whereas in 2015 it shrunk to 77 percent. In 2016, the growth rate further declined to 60 percent. Moreover, the growth and total number of electric vehicles is highly concentrated in a limited number of countries (see Figure 1).[12]

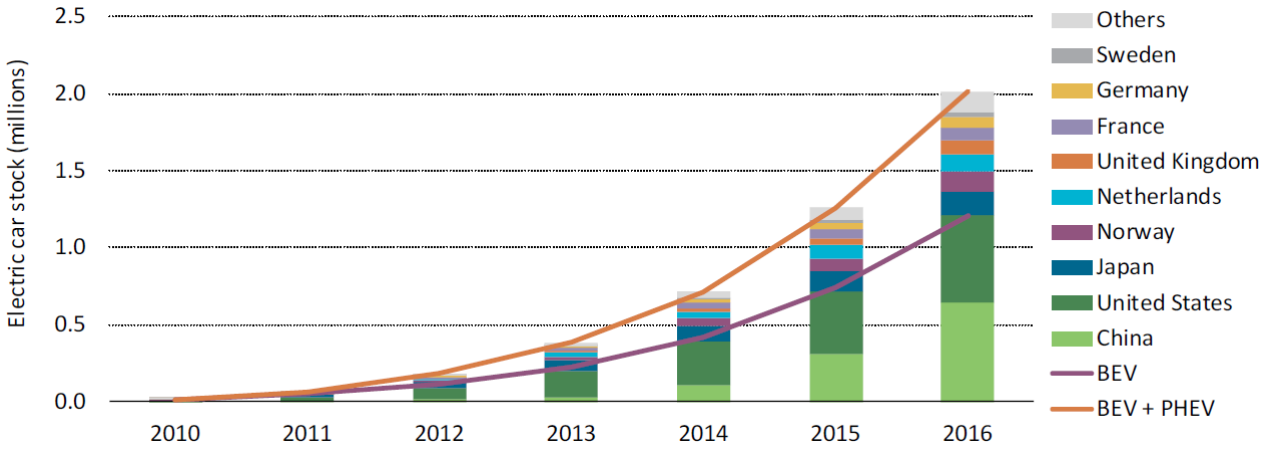


Figure 1: Development of the global number of electric vehicles from 2010 until 2016. BEV = Battery Electric Car; PHEV = Plug-in Hybrid Electric Car. Source: IEA, 2017.

In addition to the sheer number of electric vehicles, it is necessary to look at some further data. For instance, the primary cost for an electric car is the battery, which accounts for almost half the price of a mid-range car. Due to research, development and deployment (RD&D) as well as the nascent mass production of electric vehicles, respective prices for batteries have declined considerably, while the performance of batteries has been improved coincidently. As Figure 2 shows, the battery energy density has increased more than three-fold since 2010. In the same period, the battery cost has decreased by 65 percent, reaching a level of around USD 300 per kWh – despite a doubling in the price of the basic component Lithium. Tesla and General Motors have even declared that the battery cost for their new electric car models is between USD 180 and 200 per kWh.[13]

[11] Kuramochi et al., 2016; Sterl et al., 2017.
[12] IEA, 2017.
[13] Ibid.

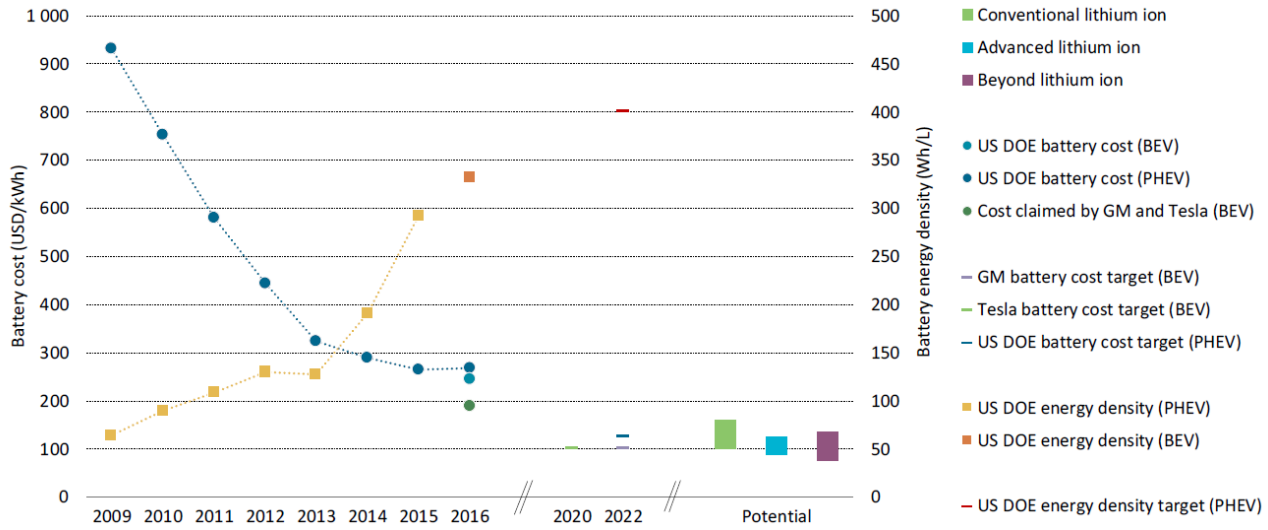


Figure 2: Development of battery cost and battery energy density. US DOE = US Department of Energy. Source: IEA, 2017.

Moreover, the charging infrastructure plays a crucial role for the proliferation of electric vehicles. Especially in cities, public chargers are important for citizens that do not have an own garage in which they can charge their car. In addition, in the future the availability of publically available chargers will be crucial to enable the management of electricity demand based on electricity supply. Privately, people tend to charge their vehicle at night when they are at home – when there is no sun shining and only soft wind blowing. In 2016, in coincidence with the number of electric cars, the total amount of chargers surpassed the boundary of two million (see Figure 3). However, most of this infrastructure is privately owned – there are six times more electric vehicles than public charging stations. Still, there was a particularly strong increase in publicly available fast chargers. The growth rate of public charging infrastructure in total was at 72 percent.[14]

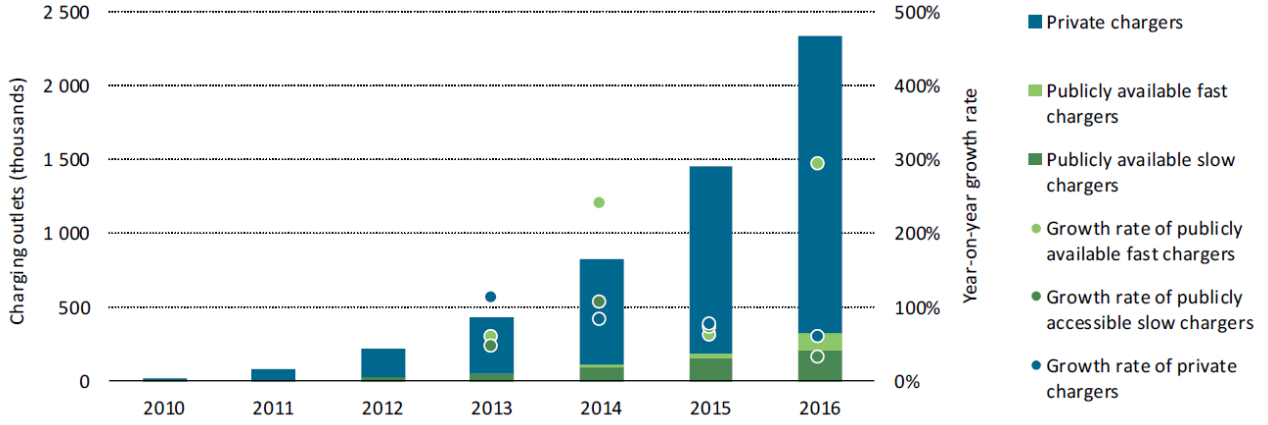


Figure 3: Development of the charging infrastructure for electric cars. Source: IEA, 2017.

As mentioned above, the number of electric cars is concentrated in a few countries. In fact, just ten countries accounted for 95 percent of global electric car sales in 2016: Canada, China, France, Germany, Japan, Netherlands, Norway, Sweden, the UK and the US. Still among these ten countries, there are large variations (see Table 1). Especially two countries shine out. First, Norway has by far the highest market share of electric vehicles with 29 percent. With its 5.2 million inhabitants, it has also the highest electric cars per capita in the world. Second, China has by far the largest market for electric cars. In 2016, it overtook the US in the total number of electric automobiles and it had an impressing share of 40 percent of global sales. Additionally, it has also

[14] Ibid.

more than 200 million electric motorcycles, three to four million low-speed electric cars and more than 300,000 electric buses. Moreover, China is the clear leader in public charging infrastructure, with a particularly great number of public fast chargers (more than 80 percent of the global fast chargers are located in China). Nevertheless, the share of electric vehicles in car sales remains relatively low at 1.4 percent – a number that is significantly lower than that of the Netherlands or Sweden (see Table 1).[15]

It is thus of course worth asking why these two countries have a leading position in the electrification of the transport sector. What concerns Norway, the country has introduced a variety of incentives, which date back to as far as 1990. Electric vehicles are exempt from several taxes and charges on toll roads and ferries. In 2018, these incentives will be reviewed and revised. Moreover, local governments can grant free municipal parking and access to bus lanes for electric cars since 2017; before, the two incentives were given country-wide.[16] Due to the clean electricity production in Norway being almost completely from hydropower, the electrification of the transport sector significantly reduces the carbon footprint of the country.[17] This is despite the fact that Norway is one of the largest exporters of oil, aiming to keep the production at the current levels over the next years.[18]

In China, support for electric vehicles is mainly driven by the aim to improve urban air quality. Thereby, strong subsidies have been awarded in the past, which partly amounted to more than 50 percent of the actual price of the electric car. As the subsidies are given only to local brands, Chinese carmakers have profited and were enabled to build economies of scale, bringing costs down. Foreign manufacturers can only access the subsidies via joint ventures with local partners. In addition, Chinese carmakers face less stringent safety regulations and put less of an emphasis on the quality of the cars compared to foreign car manufacturers. As the subsidies have already decreased and will further decline over the next years, the playing field is expected to level out. Nonetheless, from a perspective of climate change, the Chinese efforts have so far not been driving emission reductions due to the relatively carbon intensive electricity production in China.[19]

In addition to Norway and China, many other countries support the electrification of the transport sector. For instance, there are purchase subsidies in Germany, France, Sweden, the UK and the Flanders region of Belgium. Denmark, Italy, Austria, Spain and Switzerland have introduced tax benefits for electric cars. Additionally, Ireland, Portugal, several US states, South Korea, Japan and India have supporting policies in place.[20] Moreover, the plans of major cities to curb emissions from the transport sector and to improve local air quality should not be neglected.[21]

To sum up this section, the number of electric vehicles is increasing substantially. However, the share of electric cars remains almost negligible compared to the total amount of cars on the road. How are these numbers going to develop over the next years and decades? Will electric cars be able to reach a significant share in car sales and the overall car fleet? Several studies aim to give an indication in this respect, as depicted in the next chapter.

[15] Ibid.
[16] Norsk elbilforening, 2017.
[17] World Bank, 2017.
[18] EIA, 2017; NPD, 2017.
[19] Spring, 2017.
[20] Sterl et al., 2017.
[21] IEA, 2017.

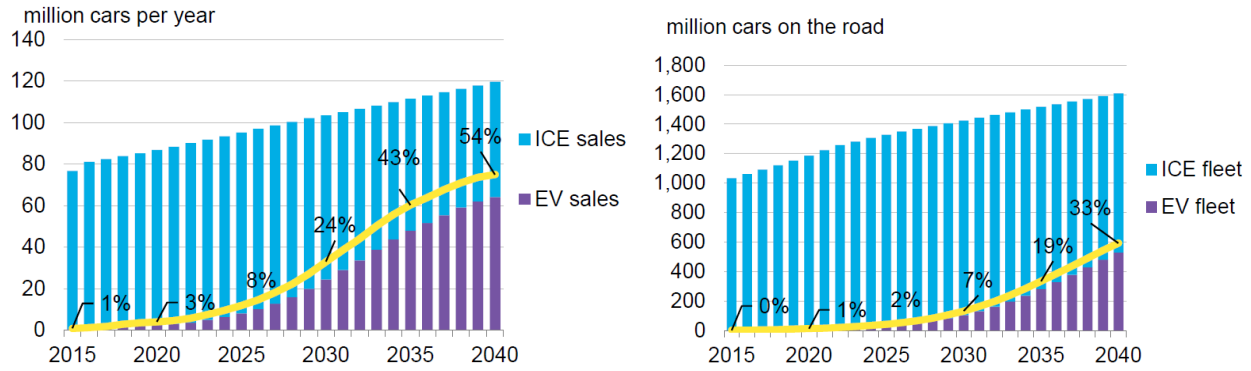
Table 1: 2016 Statistics of the ten countries with the highest numbers of electric cars as well as overview on their implemented policies. EV = Electric vehicle. Source of statistics: IEA, 2017. Sources of policy descriptions: BAFA, 2017; DOE, 2017; IEA, 2017; Ministère de la Transition Ecologique et Solidaire, 2017; Norsk elbilforening, 2017; Spring, 2017; Sterl et al., 2017.

Country	New EVs	Share EVs	Total EVs	Slow chargers	Fast chargers	Implemented Policies
Canada	11,580	0.6	29,270	3,900	320	• Tax incentives
China	336,000	1.4	648,770	52,780	88,480	• Strong financial incentives especially for local brands
France	29,510	1.5	84,000	14,610	1,230	• Tax and financial incentives when replacing old diesel and petrol cars with clean alternatives
Germany	24,610	0.7	72,730	16,550	1,400	• Financial incentive of up to EUR 4,000 (until funding of EUR 1.2 million is exhausted)
Japan	24,850	0.6	151,250	17,260	5,990	• Subsidy scheme
Netherlands	24,480	6.4	112,010	26,090	700	• Tax incentives (which have been tightened in recent years and now apply only for battery electric cars)
Norway	50,180	28.8	133,260	7,110	1,050	• Tax exemptions, exemptions from road tolls • Free municipal parking and access to bus lanes (since this year under the scope of local administrations)
Sweden	13,420	3.4	29,330	2,220	520	• Tax and financial incentives
UK	37,910	1.4	86,420	10,740	1,520	• Tax incentives
US	159,620	0.9	563,710	35,090	5,380	• Federal tax subsidy of USD 7,500 (for each carmaker until a sales number of 200,000 cars is reached) • Several states offer further financial support
Total	**753,170**	---	**2,014,220**	**212,400**	**109,870**	---

Outlook on the development of electric cars: Disagreement but large potential

What concerns the future development of electric vehicles, opinions are diverse. The conventional view is that electric car will remain a niche product with a low share of sales due to their high price and dependency on governmental support. These perspectives are especially shared by the big oil producers. BP predicts rising oil demand due to the rising demand in developing countries and Exxon Mobil expects a share of electric vehicles of only 10 percent of new car sales in the US by 2040.[22] This is largely in accordance with the World Energy Outlook of the IEA of 2016, which projects oil to remain a major foundation of the global energy system over the next decades. Nevertheless, the IEA forecasts as well a sharp increase in electric cars, with more than 30 million vehicles by 2025 and above 150 million cars in 2040 in its main scenario.[23] In contrast, the Chief Financial Officer of Shell said on a conference call last year that oil peak demand could be reached in as little as five to fifteen years as a result of efficiency improvements and substitutions in the transport sector by electric vehicles.[24]

The position of Shell matches the predictions of Bloomberg New Energy Finance (BNEF) in its Electric Vehicle Outlook 2017. BNEF expects that by 2040, 54 percent of new car sales and one third of the total car fleet will be electric. This would correspond to more than 60 million electric cars sold in 2040 and a total fleet of roughly half a million electric cars on the road. Due to decreasing prices of batteries, electric vehicles are projected to become competitive with internal combustion engine cars from 2025 on. This analysis is based on the assumption that current policies and targets will only be upheld until they expire; any additional measures are not incorporated. Thus, the modelling is mainly driven by pure economics. The numbers are significantly higher than in the outlook of 2016 due to the strong decline in battery costs and rising commitments from car producers.[25] Last year, BNEF had only predicted a share of 35 percent in sales of electric vehicles in 2040.[26]



Figures 4 and 5: Global sales of electric cars and global amount of electric vehicles on the road in the time up to 2040 according to the predictions of BNEF. Source: BNEF, 2017.

However, there are also more optimistic forecasts. According to the Climate Action Tracker, cost parity of electric cars with conventional ones could be reached as soon as 2020.[27] Another study of the Grantham Institute and the Carbon Tracker predicts a share of electric cars in overall sales of 35 percent by 2035 and over two thirds by 2050.[28] Even more disruptive is a study of the think tank RethinkX, which focuses on the development of transport-as-a-service. The transport-as-a-service notion emanates from ride-hailing approaches, such as Uber. It springs from the joint usage of autonomous electric vehicles as a merger of public and private transportation, which is considered as a tremendous low-cost transport alternative. As a result, the study projects that within ten years

[22] BP, 2017; Exxon Mobil, 2017.
[23] IEA, 2016.
[24] Katakey, 2016.
[25] BNEF, 2017.
[26] BNEF, 2016.
[27] Sterl et al., 2017.
[28] Sussams and Leaton, 2017.

as much as 95 percent of passenger miles could be provided by transport-as-a-service, leading inter alia to a substantive reduction of GHG emissions from the transport sector in case of a concurrent development in the electricity sector towards renewable energies.[29]

If the latter scenario is indeed realistic, is anyone's guess. In any case, many countries have set or are in the process of setting targets for the proliferation of electric vehicles. Several countries have even defined a year, in which they plan to ban the sale of petrol and diesel cars (see Table 2). In addition, several carmakers have made announcements on how they intend to promote electric vehicles through investments and targets. These commitments have particularly been made or been extended in the wake of the Volkswagen dieselgate scandal (see Table 3).

This gives a promising view on the future development of electric vehicles. Nevertheless, the goals fall short of the requirements outlined above to adhere to the goals of the Paris Agreement. Moreover, there are some additional challenges to overcome if electric vehicles are to make a major contribution for the decarbonisation of the transport sector. This will be the topic of the last section.

Table 2: Targets of selected countries for the promotion of electric vehicles.

Country	Target
China	• Share of alternative fuel vehicles of at least 20 percent of sales in 2025, which would correspond to more than 7 million cars • Target of 2 million electric car sales in 2020
European Union	• EV chargers at parking spaces of 10 percent of buildings by 2023 • Emission reduction target for new cars of 95 gCO_2 per km by 2021 • Several EU member states have individual targets for electric car diffusion
France	• Ban of petrol and diesel car sales by 2040
Germany	• Federal Council has passed a position to ban petrol and diesel car sales by 2030 but the government rejected the demand • Goal of one million electric vehicles by 2020 (dismissed) and six million by 2030
India	• Ban of petrol and diesel cars by 2030 • Target of 6 to 7 million electric vehicles in total by 2020
Netherlands	• Ban of petrol and diesel car sales by 2025 was passed in the lower house of the Parliament but not (yet) in the senate
Norway	• Ban of petrol and diesel car sales by 2025
UK	• Ban of petrol and diesel car sales by 2040

Sources: Basu, 2017; Behrmann and Delfs, 2017; Böll, 2016; Department for Environment, Food & Rural Affairs and Department for Transport, 2017; EC, 2017; Hern, 2016; Hockenos, 2017; Jourdan, A., 2017; Ministère de la Transition Ecologique et Solidaire, 2017; Norsk elbilforening, 2017; PTI, 2017; Sterl et al., 2017; Tagesschau, 2016.

[29] Arbib and Seba 2017.

Table 3: Announcements by several major carmakers with respect to electric vehicles.

Carmaker	Announcement
BMW Group	• 100,000 electric vehicles sales in 2017 • 15-25 percent electric vehicle share by 2025
Chevrolet	• 30,000 electric vehicle sales by 2017
Chinese OEMs	• 4.52 million electric car sales by 2020
Daimler	• 100,000 electric car sales by 2020 • 15-20 percent battery electric vehicles share of sales by 2025 • 10 percent hybrid electric vehicles share of sales 2025 • 10 new electric vehicle models by 2022 • Investments of EUR 10 billion until 2022 into electric vehicles
Ford	• 13 new electric car models by 2020
Honda	• Electric vehicles with a share of two thirds of sales in 2030
Renault-Nissan	• 1.5 million electric car sales by 2020 • Investments of EUR 4 billion into electric cars as announced in 2009
Tesla	• 500,000 electric vehicle sales by 2018 • 1 million electric vehicle sales by 2020
Volkswagen	• 2-3 million electric car sales by 2025 with 30 new battery-powered car models, which would correspond to 25 percent of vehicle production • Investments of EUR 9 billion until 2022 into electric vehicles
Volvo	• 1 million electric car sales by 2025 • No new car model without an electric motor from 2019 on

OEM = Original equipment manufacturer. Sources: Behrmann and Delfs, 2017; IEA, 2017; MacLellan and Faulconbridge, 2017; Peng and Tan 2017; Volvo Car Group, 2017.

Challenges and risks of electric vehicles: Social and technical implications

There is a set of challenges that need to be tackled in order for electric vehicles to become mainstream and to significantly reduce the carbon footprint in the transport sector. First of all, it needs to be taken into account out of a perspective focusing on climate change that electric cars are only as clean as their source of power. Therefore, the decarbonisation of the electricity sector is a major prerequisite for reducing emissions with electric vehicles in the transport sector. In addition, the diffusion of electric vehicles will lead to a substantial increase in demand for electricity. Thus, the charging of electric vehicles will have to be managed in a way to balance out supply and demand for electricity.[30] How great the impact of electric vehicles on the total electricity consumption will be is controversial, depending on the assumptions of demand management. The Electric Vehicle Outlook 2017 of BNEF predicts in this consideration a 300-fold rise between 2016 and 2040. This translates into a share of electric vehicles of 5 percent of the total global power demand in 2040.[31]

In addition, the driving range and the charging infrastructure need to be improved for the proliferation of electric cars. The lack of charging infrastructure might represent a barrier for the penetration of electric vehicles in the car market, even if they have reached price parity with conventional cars.[32] While the range of electric vehicles is already sufficient to satisfy the daily trips of most people and has improved to as much as 500 kilometres for new car models, concerns remain persistent.[33]

[30] Sterl et al., 2017.
[31] BNEF, 2017.
[32] Ibid.
[33] Plumer, 2017.

Another major issue is the availability of necessary resources and the circumstances under which they are mined and extracted. According to the Electric Vehicle Outlook 2017 of BNEF, the demand for lithium-ion batteries from electric cars will grow more than 60 times from 2016 until 2030.[34] A World Bank study even estimates that the spread of electric storage batteries (thus encompassing not only batteries for electric vehicles) under a scenario compatible with the 2°C-target would lead to a 1000-percent increase in certain metals.[35] Concerning lithium, it should be taken into account that the mineral only represents about two percent of lithium-ion batteries. Research indicates that the quantities are sufficient to meet the demand, if it is planned for the rising need. This is because it takes about three to five years to open respective mines and to build required refinery capacities. However, the lithium production is highly concentrated in a few countries and among major producers. Moreover, an increasing proportion will have to stem from crushing rocks rather than brining, which is more energy-intensive. Nevertheless, as a stock material, any limitations of lithium would only affect new electric cars. [36] Furthermore, one reason for the low share of lithium-ion batteries being recycled so far (only around five percent) is the low quantity of battery material to keep recycling facilities economically viable. This will certainly change in the future.[37] Besides, there are many different types of lithium-ion batteries, which rely on different minerals. Hence, minerals can be substituted to a certain degree. However, the most common form of batteries use minerals such as cobalt and nickel[38] – two minerals having among the highest potential environmental impacts, as they require massive amounts of water and toxic chemicals[39]. In case of cobalt, more than 60 percent of supply comes from the Democratic Republic of the Congo, a high-conflict country.[40] According to UNICEF, more than 40,000 children worked in the mining sector of the country in 2012.[41] In addition, there are further examples of disregarding social and environmental standards. In general, the scrutiny of the supply chains for electric vehicles is more detailed than it is the case for consumer electronic devices due to the green image of electric cars.[42] This might help to improve the mining conditions and the overall environmental performance of the cars.

Beyond that, electric cars require substantially fewer parts than a conventional car, which in turn leads to less maintenance and service needs. A study commissioned by the interest group of the German automobile industry VDA concluded that in case of a ban of petrol and diesel cars by 2030 about 620,000 jobs in the Germany industry would be directly or indirectly affected. The directly affected 457,000 jobs correspond to 7.5 percent of jobs in the German industrial sector. Nevertheless, it is uncertain if the jobs at risk would be indeed destroyed. Moreover, the study acknowledges that a certain percentage of jobs would be compensated by the expansion in the area of alternative modes of driving.[43]

Besides, the impacts of the rise of electric vehicles on oil demand need to be considered. A faster-than-expected proliferation of electric vehicles may lead to a considerable amount of stranded assets, such as of pipelines and infrastructure for offshore drilling and for oil sands production. Moreover, the decrease of oil revenues could result in a destabilisation of oil-producing countries, especially if there are only small financial safety nets as in the case of Venezuela and Nigeria.[44]

Moreover, state revenues from conventional fuel taxes will decrease with increasing penetration of electric vehicles. This will require a shift to alternative taxation, such as road tolls, in order to maintain and develop the road transport infrastructure.[45]

[34] BNEF, 2017.
[35] World Bank, 2017.
[36] Sussams and Leaton, 2017.
[37] Sanderson, 2017.
[38] Sussams and Leaton, 2017.
[39] EPA, 2013.
[40] Sussams and Leaton, 2017.
[41] Walther, 2012.
[42] Sanderson, 2017.
[43] Falck et al., 2017.
[44] Sussams and Leaton, 2017.
[45] IEA, 2017.

Last but not least, out of a climate change perspective, progress is also required in the case of transportation modes other than light-duty passenger cars. Technologies for the electrification of heavy-duty vehicles, such as trucks and buses are not as advanced. In addition, the electrification of airplanes and large ships seems to be less of an option, requiring the utilisation of biofuels, efficiency improvements and other innovations.[46]

Conclusion

To conclude, electric vehicles are making unexpectedly fast progress, similar to the recent development of renewable energy technologies such as solar and wind power. The sales and total numbers are rising and the outlook is promising in most projections. However, in order to attain the targets of the Paris Agreement, an even faster penetration of electric cars in the transport sector is required, which is why governmental support will be crucial in the short- to mid-term. Moreover, a plethora of challenges has to be addressed. It is particularly crucial that the decarbonisation of the electricity and the transport sector go hand in hand. Moreover, social and environmental safeguards should ensure that the sourcing of materials required for the production of electric vehicles is sufficient to meet the demand, as well as environmentally and ethically sound.

[46] Kuramochi et al., 2017.

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