

Electric vehicles in Europe



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Luxembourg: Publications Office of the European Union, 2016

ISBN 978-92-9213-804-2
ISSN 1977-8449
doi: 10.2800/100230

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Abbreviations and acronyms

AC	Alternating current
ACEA	European Automobile Manufacturers' Association
BEV	Battery electric vehicle
CO ₂	Carbon dioxide
DC	Direct current
EAFO	European Alternative Fuels Observatory
EEA	European Environment Agency
Eionet	European Environment Information and Observation Network
FCEV	Fuel cell electric vehicle
GHG	Greenhouse gas
HEV	Hybrid electric vehicle
kWh	Kilowatt-hour
NO ₂	Nitrogen dioxide
NO _x	Nitrogen oxides
PHEV	Plug-in hybrid electric vehicle
PM	Particulate matter
REEV	Range-extended electric vehicle
SO ₂	Sulphur dioxide
TCO	Total cost of ownership
VAT	Value added tax
WHO	World Health Organization

Acknowledgements

This report was prepared by the European Environment Agency (EEA). The EEA project manager was Magdalena Józwicka. The text was based on a study commissioned by the EEA under Framework Contract No EEA/ACC/13/003 and authored by Florian Hacker, Friederike Hülsmann, Sven Kühnel, Lukas Minnich (Öko-Institut), Joko Purwanto (Transport & Mobility Leuven) and Mark Bolech (Netherlands Organisation for Applied Scientific Research, TNO). EEA colleagues, European Commission and European Environment Information and Observation Network (Eionet) countries are thanked for their support during the preparation of this report.

Scope of this report

This report provides a non-technical summary of the latest information on electric road vehicles in Europe, including those with hybrid technologies. It focuses upon electric passenger vehicles, explaining the different types that are now available on the market, how each type works, and their respective advantages and disadvantages. The report also outlines how many countries in Europe are presently using incentives to encourage the further uptake of electric passenger vehicles, and it identifies the main barriers restricting their broader use. The latest information on electric passenger car and van sales in Europe is provided.

While the report includes a brief description of other types of electric road vehicles, including bicycles, vans, heavy-duty vehicles and buses, other types of electric transport, such as electric rail locomotives and ships, are not addressed.



On the path to a more sustainable transport system

Transport underpins our society. It connects people, cities, countries and economies, fostering growth and employment. However, transport also damages the climate, the environment and human health. To reduce these impacts, Europe needs to move towards a more sustainable circular economy and decarbonised transport system.

Despite past technological improvements, the transport sector is responsible for around one quarter of Europe's greenhouse gas (GHG) emissions, contributing to climate change. Emissions from road vehicles also contribute to high concentrations of air pollutants in many of Europe's cities, which often don't meet air quality standards set by the European Union (EU) and the World Health Organization (WHO). Furthermore, road transport is the main source of environmental noise pollution in Europe, harming human health and well-being.

The EU is committed to developing a more sustainable circular economy and decarbonised transport system. Developing a circular economy that inter alia aims to increase resource efficiency is key in realising the second main objective of the 7th Environment Action Programme, that the EU should turn into a resource-efficient, green and competitive low-carbon economy (EU, 2013). To focus this transition, a number of future targets have been set to reduce the environmental impacts of transport in Europe.

The transport sector's GHG emission reduction targets are, for example, designed to contribute to the EU's overall goal to reduce GHG emissions by 80–95 % by 2050. In its 2011 Transport White Paper (EC, 2011), the European Commission outlined a roadmap for the transport sector to achieve, by 2050, a 60 % reduction in its GHG emissions levels compared with those of 1990. The White Paper shows how the transition to a more sustainable transport system can be achieved, and how Europe's reliance on oil can be reduced. It also supports the development and deployment of new and sustainable fuels and propulsion systems. Moreover, it describes goals for a competitive and resource-efficient transport system, including benchmarks such as:

- halving the use of conventionally fuelled cars in urban transport by 2030 and phasing them out entirely in cities by 2050;
- setting a 40 % requirement for the use of sustainable low-carbon fuels in aviation;
- shifting the amount of freight transported by road to other transport modes, 30 % by 2030 and 50 % by 2050, for distances over 300 km.

Transport's impacts on the environment

Greenhouse gases

While GHG emissions from all other major economic sectors have fallen in recent decades, those from transport have increased. In the EU, road transport's emissions are today around 17 % above 1990 levels, while the contribution of road transport to total EU GHG emissions has increased by around half — from 13 % of the total in 1990 to almost 20 % in 2014. The EU is committed to reducing the fuel consumption of road vehicles, to both lower GHG emissions and improve energy security. Vehicles have become more fuel-efficient over recent decades. However, there is wide recognition that the official test procedure used to measure emissions is out-dated and does not accurately represent real-world driving conditions. Real-world driving CO₂ emissions are now around 30–40 % higher than officially declared emissions (ICCT, 2014). The EU is, however, updating procedures for measuring emissions to better reflect actual vehicle performance on the road, with certain new measures scheduled for introduction from 2017 onwards.

Air pollution

Road transport remains an important source of harmful air pollutants such as nitrogen oxides (NO_x) and particulate matter (PM). Pollution released by vehicles is particularly important for health, as these emissions generally occur close to the ground and in areas where many people live and work, such as cities and towns. Therefore, emissions from the road transport sector can be more harmful than those from other sources, such as power plants or large industrial facilities, which often tend to be in remoter, less populated areas. Emissions of the main air pollutants from transport have generally declined over the past two decades. However, many of Europe's urban dwellers remain exposed to air pollution levels that exceed EU air quality standards. For example, the EU annual limit value for nitrogen dioxide (NO₂), the harmful component of NO_x, was widely exceeded across 19 Member States in 2013, mainly at roadside locations (EEA, 2015a). On average, more than 60 % of NO₂ air pollution at such locations comes from road traffic. In some areas, the contribution attributable to traffic exceeds 80 %. Similarly, a number of Member States report PM levels higher than the EU air quality standards.

More recently, the European Commission has published a European strategy for low-emission mobility (EC, 2016). The longer-term objectives of the new strategy are to decrease oil import dependency, increase innovation and competitiveness and foster opportunities for growth and jobs. Furthermore, it highlights the importance of removing obstacles to the electrification of

transport, and improving the efficiency of Europe's transport system by moving towards low and zero-emission vehicles as well as scaling up the use of low-emission alternative energy sources such as renewable electricity.

In the future, it is clear that a large share of the planned GHG emissions reductions will have to come from road transport through the use

Noise

Road traffic is by far the main source of traffic noise in Europe, both inside and outside urban areas. High levels of noise harm human health and well-being. In 2012, almost 90 million people living in cities were exposed to long-term average road traffic noise levels exceeding EU thresholds. At night, over 83 million people were exposed to high levels of road noise (EEA, 2014). The noise from vehicles comes from two main sources: the engine and the contact between the tyres and the road. Tyre noise increases more than engine noise with increasing speed, and predominates at high speeds. At low speeds, such as in cities, engine noise is relatively more important because of frequent acceleration and deceleration. At higher speeds (upward of approximately 50 km/h) the noise difference between electric and conventional vehicles is negligible.

Resource use and waste

Manufacturing vehicles, both conventional and electric, requires significant amounts of raw materials and energy. Furthermore, many of the raw materials needed for manufacturing are either not available in Europe or not available in sufficient quantities, and so must be obtained and transported from other parts of the world. Within the EU, end-of-life vehicles also create many millions of tonnes of waste each year. While some vehicle parts can be recycled, the rate of recycling generally depends upon the types of materials used in production as well as the economics of recovery compared to the costs of acquiring raw materials.

of new, cleaner technologies and by reducing transport oil consumption. This will require a considerable effort, especially as the transport sector is the only major economic sector that has increased GHG emissions since 1990.

Making internal combustion engines more efficient is unlikely to be sufficient by itself to achieve the EU's long-term goals of reducing emissions. Instead, an integrated approach is needed, covering vehicle efficiency, renewable fuels as well as measures that help reduce transport demand itself.

Electric vehicles are just one of the potential ways in which Europe can move towards a more sustainable transport system. Other key factors in increasing the sustainability of transport will include further development

of renewable biofuels, a shift towards non-motorised and/or public transport, and changing the ways in which we use our transport systems.

Replacing conventional vehicles with electric vehicles can help reduce emissions, although how much it helps depends significantly upon the source of the electricity used to charge vehicles: renewable sources, nuclear power or fossil fuel. However, simply replacing conventional vehicles will not solve other problems such as growing congestion or increasing demand for road infrastructure and parking. In the short and medium term, it is clear that Europe will still have to rely on conventional road vehicles, while new and cleaner technologies develop.



Electric vehicles: how do they work?

A hybrid vehicle includes both a conventional engine and a battery-powered electric motor, which adds to the complexity of vehicle systems. Electric vehicles, powered by a battery alone, also have a greater number of specialised components than conventional vehicles.

Over the past decade, vehicle manufacturers have introduced a number of alternative engine technologies. These include battery electric vehicles that include a number of specialised parts, including the battery, an electric motor, an engine controller and regenerative brakes. 'Hybrid' vehicles include all the same main parts as a battery electric vehicle, as well as having a conventional main or auxiliary combustion engine and associated fuel tank.

Electric motor

An electric motor powers the vehicle using electrical energy stored in the battery. An electrical motor can also act as an on-board generator for the battery by producing electricity while the vehicle is decelerating. Electric motors have several advantages over conventional combustion engines. This includes their higher efficiency (an electric vehicle converts around 80 % of the energy it uses to usable power, compared with around 20 % for a conventional vehicle), high durability, lower maintenance costs and quieter noise levels at low speeds.

Different types of electric motor are used in electric vehicles, including alternating current (AC) induction motors, and different types of direct current (DC) motors. In general, the different

technologies underpinning electric motors are considered fairly well developed in terms of their efficiency and reliability. Nevertheless, some costs associated with their production are likely to go down in the future thanks to more efficient production systems, improved designs and smaller motors (NRC, 2013).

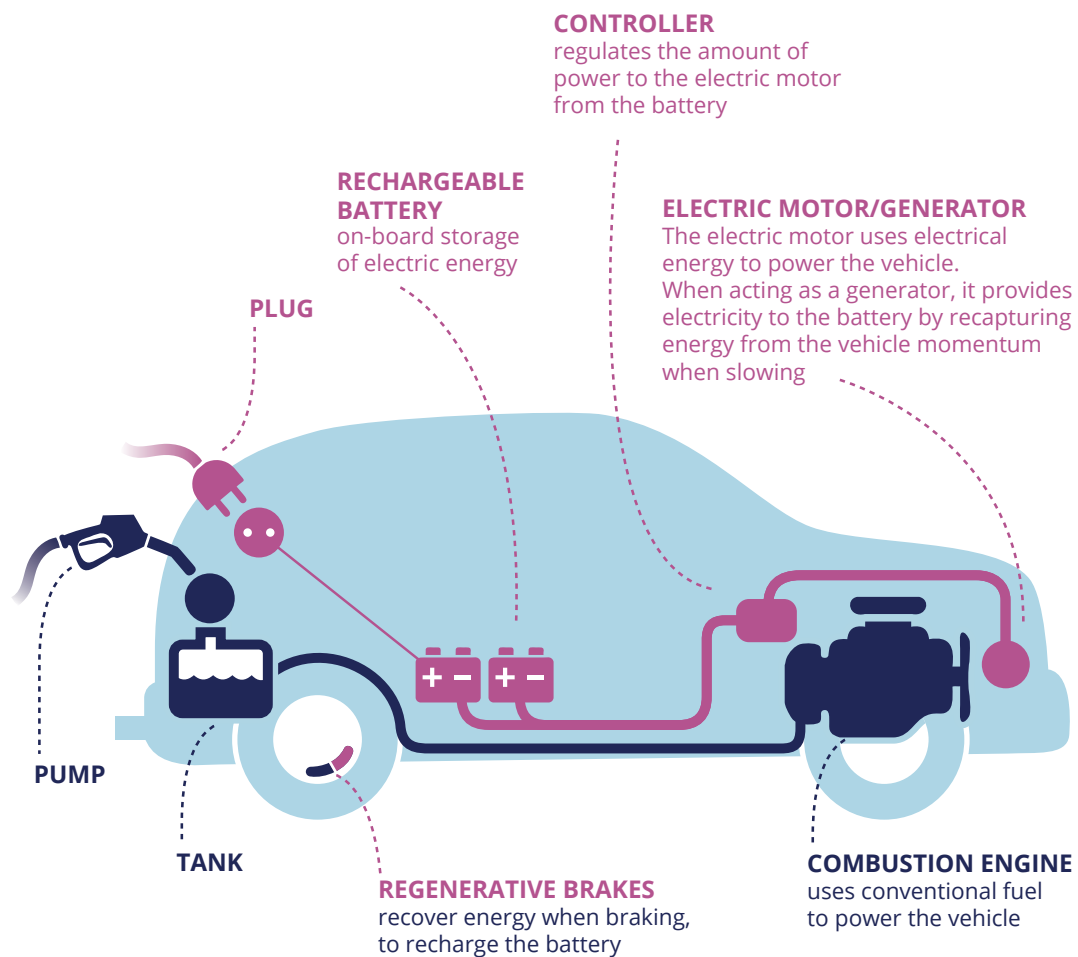
Batteries

The battery in an electric vehicle stores electrical energy that the electric motor uses to power the vehicle. Most electric vehicles use lithium-ion batteries. These have certain advantages over most other battery types, including higher energy storage capacity and longer lifespans. However, current battery systems tend to be both heavy and costly. Furthermore, even if batteries are used according to the manufacturer's instructions, they lose capacity over time as a result of ageing and repeated charging cycles. Developing improved battery technologies is a major priority for further research and development.

Controller

The electric motor controller governs the performance of the electric motor, including regulating the amount of power that the battery supplies to the motor.

The main parts of an electric car



● ELECTRIC VEHICLE ●+ PLUG-IN HYBRID VEHICLE

Regenerative brakes

Regenerative braking systems help keep the battery in an electric vehicle charged, by converting into electricity much of the energy that would normally be lost as heat during braking. Such systems include a small electrical generator as part of the vehicle's braking systems; they must be used together with conventional friction-based brakes. One additional advantage of regenerative brakes, apart from improving the overall energy efficiency of the vehicle, is that they extend the life of the vehicle's braking system, as its parts do not wear out so quickly.

Auxiliary equipment

Like conventional vehicles, electric vehicles incorporate several types of auxiliary equipment. These include power steering, braking support, lights, passenger cooling and heating systems, and battery heating and cooling systems. Especially during cold periods, both the battery and passenger heating systems can consume much of the battery capacity, potentially reducing driving range. Optimising energy use by auxiliary equipment becomes more important in electric vehicles.

A closer look at electric vehicle batteries

The battery is a core component of electric vehicles. Depending on the type of electric vehicle or hybrid, batteries have different technical characteristics that determine how much electricity is stored as well as how fast the stored energy can be released and made available to power the vehicle.

The performance of batteries can be defined by several measures, including:

Energy density: a measure of how much electrical energy can be stored per unit volume or mass of the battery. This measure is relevant to vehicle range, as batteries with a higher energy density are typically able to power a vehicle for longer distances.

Power density: a measure of power per unit volume, i.e. how fast a battery can deliver or take on charge. This measure is more relevant for driving performance, i.e. acceleration and driving speed, and charging times. Lithium-ion batteries are today the most widely used type of battery in electric vehicles. A compact lithium-ion battery used in a small electric car (approximately 900 kg) contains around 4 kg of lithium. In comparison with other battery technologies, lithium-ion batteries have a relatively high energy density, although they provide only around one tenth of the energy density of fuel used for internal combustion engines. They also have low self-discharge rates, i.e. how much energy is lost over time and so which cannot be used for driving. Such batteries can typically last for around 10 years, and can be charged 2 500–3 500 times (BU, 2016).

Lithium-ion batteries can also operate over a relatively wide temperature range, although they are less efficient at extremes of hot and cold. Most lithium-ion batteries can be charged only between 0 °C and 45 °C. To protect batteries, some vehicles include a heating and cooling system to help ensure that battery charging and operation occurs within the optimal temperature range.

However, the costs of manufacturing lithium-ion batteries are high and the cost of the battery can be a significant fraction of the total electric vehicle price. The actual raw material cost of the lithium used makes up only a small fraction of the total battery costs, typically only up to 10 % of the total battery costs (BU, 2016; Qnovo, 2016). A EUR 10 000 battery for a plug-in hybrid therefore contains around EUR 1 000-worth of lithium.

The main drawbacks of the currently available lithium-ion battery technologies are their still-limited energy density and the high costs of manufacture. While the detailed cost structure of manufacturing batteries is generally confidential, it is estimated that they break down into: material costs (60 %),

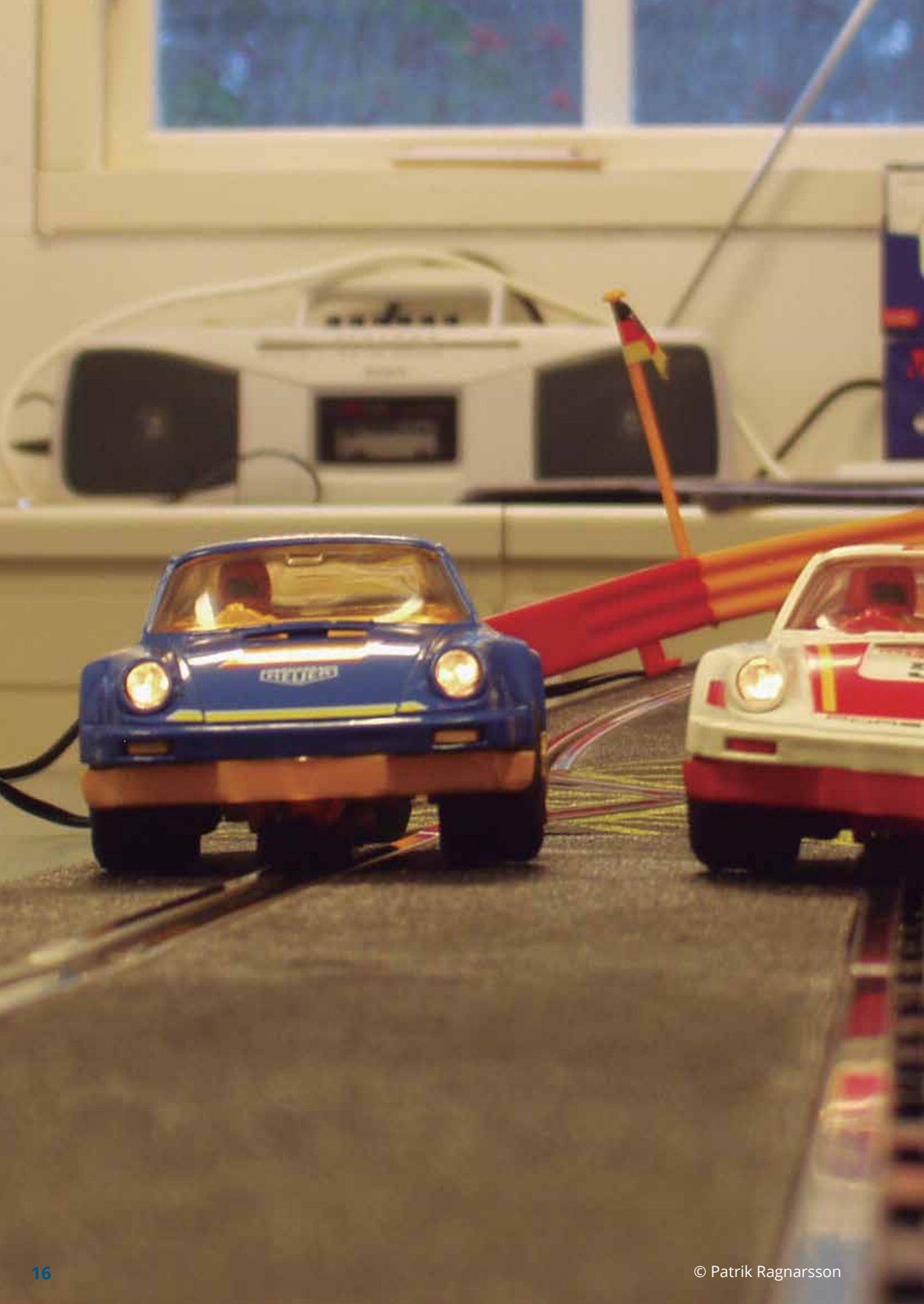
labour costs (5 %), and the rest (35 %) is manufacturing overhead and profit (Qnovo, 2016). However, industry-wide estimated costs for battery manufacture reportedly declined by approximately 14 % a year between 2007 and 2014, a total drop of nearly 60 %, and continue to decline (Nykqvist and Nilsson, 2015). Further cost reductions can be achieved by developing the so-called second generation of lithium-ion batteries, as well as by optimising manufacturing processes with economies of scale, innovative manufacturing, reduction of waste and potentially using alternative, less expensive, materials (ICCT, 2016).

To improve the electric driving range considerably, different battery technologies such as lithium-sulphur or solid state

batteries are also being explored. Such technologies could potentially greatly increase battery capacities compared with current lithium-ion battery technologies. However, these new technologies are still at an early stage and do not yet comply with current requirements for battery lifetime and safety. Their durability is expected to improve in the future, but their performance in different temperatures is currently very uncertain.

The environmental impacts associated with battery manufacture and end-of-life disposal are discussed in the section 'How environmentally friendly are electric vehicles?'





The different types of electric vehicles

Consumers have a choice between several different types of hybrids, pure battery electric vehicles and vehicles powered by fuel cells. But understanding the basic differences between these technologies, and their advantages and disadvantages, is not always straightforward for consumers.

Vehicle manufacturers presently use five main types of electric vehicle technology. These technologies vary in the way the on-board electricity is generated and/or recharged, and the way the internal electric motor and combustion engine are coupled. The mix of battery capacities, charging capabilities and technological complexity provides consumers with a choice of options when it comes to vehicle ranges, refuelling options and price.

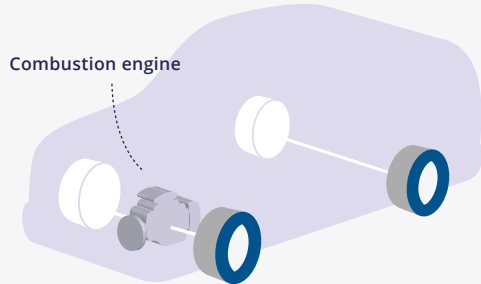
The following sections describe each of the main electric vehicle and hybrid technology types, how each works, and their associated advantages and disadvantages.

Conventional vehicles

Conventional vehicles use fossil fuels (e.g. petrol or diesel) to power an internal combustion engine. While driving, they produce noise and exhaust emissions that pollute air. Conventional vehicles are inefficient, only about 18 to 25 % of the energy available from the fuel is used to move it on the road. Such vehicles have been mass-produced for over a century, and a substantial support infrastructure comprising vehicle manufacturing, repair and refuelling facilities has accordingly been developed.

Conventional vehicle

Conventional vehicles use an internal combustion engine (petrol/diesel) to provide vehicle power.



ADVANTAGES

- CHOICE OF DIFFERENT MODELS
- MANY REFUELLING STATIONS

DISADVANTAGES

- EXHAUST EMISSIONS
- FOSSIL FUEL DEPENDENCY
- HIGHER ENGINE NOISE
- LOW ENERGY EFFICIENCY

Battery electric vehicles (BEVs)

BEVs are powered solely by an electric motor, using electricity stored in an on-board battery. The battery must be regularly charged, typically by plugging in the vehicle to a charging point connected to the local electricity grid. BEVs have the highest energy efficiency of all vehicle propulsion systems, typically able to convert around 80 % or more of the energy stored in the battery into motion. The electric motor is particularly efficient, and regenerative braking provides further efficiency gains. Regenerative braking systems help keep the battery in an electric vehicle charged, by converting into electricity much of the energy that would normally be lost as heat through traditional braking.

There are no exhaust emissions while driving a battery electric vehicle. This helps to improve local air quality. The greatest benefits for the environment occur when BEVs are powered by electricity from renewable sources. However, there are fewer emissions even when electricity comes from the average mix of renewables and fossil fuels used presently in Europe (EEA, 2016a). In the EU-28, almost 30 % of electricity was produced from renewables in 2014 (Eurostat, 2016).

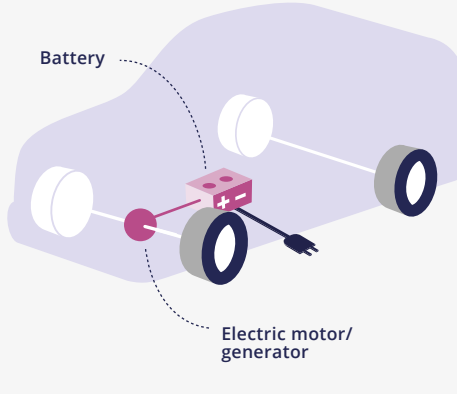
BEVs, however, still have somewhat limited driving ranges compared to conventional vehicles and typically need a long time to recharge the on-board batteries. BEVs tend to have large batteries to maximise the energy storage capacity and hence allow longer driving

ranges. These large batteries generally cost more than those used in hybrids. However, battery costs per kilowatt-hour (kWh) tend to be less expensive for BEVs.

Indicative electric driving range: 80–400 km.

Battery electric vehicle

Battery electric vehicles are powered by an electric motor and battery with plug-in charging.



The diagram shows a top-down view of a car chassis. A large red battery pack is located in the rear. A red electric motor/generator is positioned in the front. A charging cable is plugged into the front of the car.

ADVANTAGES

- HIGHER EFFICIENCY
- HOME/WORKPLACE RECHARGE
- LOW ENGINE NOISE
- ZERO EXHAUST EMISSIONS

DISADVANTAGES

- FEWER RECHARGING STATIONS
- LONG TIME TO RECHARGE
- SHORT DRIVING RANGE

Hybrid electric vehicles (HEVs)

HEVs have been commercially available for more than 15 years. They combine an internal combustion engine and an electric motor that assists the conventional engine during, for example, vehicle acceleration. The battery of an HEV cannot be charged from the grid but is typically charged during regenerative braking or while the vehicle is coasting.

As an HEV is predominantly powered by its conventional engine, hybridisation can be regarded as a technology added to conventional vehicles with the aim of increasing fuel efficiency, reducing pollutant and CO₂ emissions, rather than being an entirely separate type of vehicle.

HEVs typically have lower fuel consumption and exhaust emissions than conventional technologies. The more sophisticated the hybrid system, the greater the potential to lower emissions. Many different types and models of HEVs exist, ranging from 'micro-HEVs', whose only fuel-saving feature is regenerative braking and where the electric engine on its own is not capable of powering the vehicle, through to 'full HEVs', which are able to drive small distances in electric-only mode.

The ways in which the conventional engine and electric motor are joined can also differ across different HEV models. *Parallel hybrids* employ an electric motor and a combustion engine that are connected so they power the vehicle together. *Series-parallel hybrids*, or power-split hybrids, combine power from the conventional and electric motors to drive the wheels but, unlike a parallel hybrid, these vehicles can be driven from the battery alone, although typically only at low speeds for short distances. Their configuration can allow the vehicle to be powered 100 % from

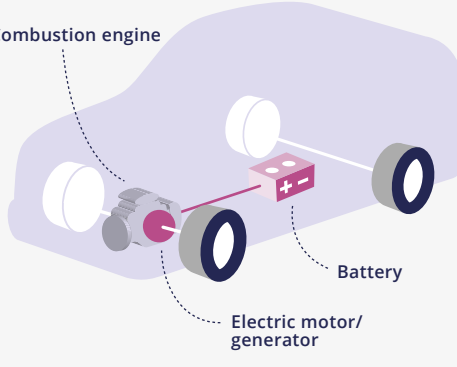
the conventional engine, 100 % from the electric motor or in any intermediate ratio, e.g. 30 % electric motor and 70 % combustion engine.

Batteries for hybrids, both plug-in and non-plug-in, tend to be more expensive than the ones for battery electric vehicles in terms of price per kWh. This higher price is mainly because hybrid vehicles require greater power-to-energy performance.

Indicative electric driving range: 0–10 km.

Hybrid electric vehicle

Hybrid electric vehicles combine a conventional (petrol/diesel) engine and a small electric motor/battery charged via regenerative braking or the engine.



The diagram shows a top-down view of a car chassis. A combustion engine is located in the front. A red battery pack is located in the rear. An electric motor/generator is positioned between the engine and the battery.

ADVANTAGES

- HIGHER EFFICIENCY
- MANY REFUELLING STATIONS

DISADVANTAGES

- EXHAUST EMISSIONS
- FOSSIL FUEL DEPENDENCY
- HIGHER ENGINE NOISE
- TECHNOLOGICAL COMPLEXITY

Plug-in hybrid electric vehicles (PHEVs)

PHEVs are powered by an electric motor and an internal combustion engine designed to work either together or separately. The on-board battery can be charged from the grid, and the combustion engine supports the electric motor when higher operating power is required or when the battery's state of charge is low.

The electric driving range is smaller than for BEVs, as the batteries tend to have smaller capacities. The batteries can have less energy storage capacity because they rely less on electrical power alone to power the vehicle. The battery capacity in PHEVs is designed more for short trips in the city or commuting, for example, than for long-distance journeys. However, as for REEVs, the combustion engine allows a much longer overall driving range.

Batteries for PHEVs tend to be more expensive than for BEVs in terms of price per kWh. This higher price is mainly because PHEVs require greater power-to-energy performance.

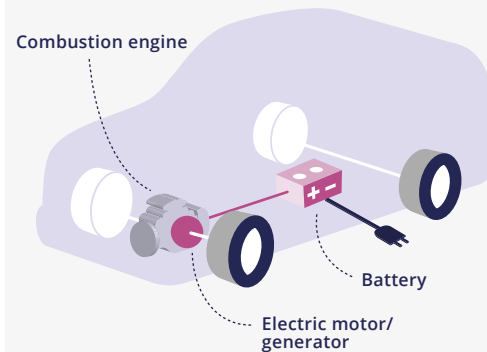
The environmental impact of PHEVs depends on their operation mode. Running in all-electric mode results in zero exhaust emissions, but relying only on the conventional engine can lead to fuel consumption and emission levels equal to or higher than those of conventional vehicles of a similar size, because the additional batteries increase the vehicle mass. Moreover, as for BEVs, the overall environmental performance of PHEVs depends greatly on the share of

renewables in the electricity generation mix. PHEVs can be financially attractive for drivers if the electricity used is cheaper than the petrol or diesel that would have otherwise been used.

Indicative electric driving range: 20–85 km.

Plug-in hybrid electric vehicle

Plug-in hybrid electric vehicles have a conventional (petrol/diesel) engine complemented with an electric motor/battery with plug-in charging.



ADVANTAGES



DISADVANTAGES



Range-extended electric vehicles (REEVs)

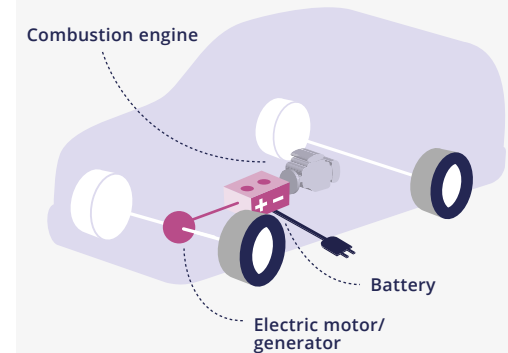
REEVs have a serial hybrid configuration in which their internal combustion engine has no direct link to the wheels. Instead the combustion engine acts as an electricity generator and is used to power the electric motor or recharge the battery when it is low. The on-board battery can also be charged from the grid. The electric motor is therefore solely responsible for directly powering the vehicle.

One advantage of REEVs is that the conventional engine can be small, as it is needed only when the vehicle exceeds its electric driving range. This helps reduce the vehicle's weight. As for a PHEV, an REEV overcomes the problem of a restricted driving range associated with BEVs because it can be fuelled at conventional filling stations.

Indicative electric driving range: 70–145 km.

Range-extended electric vehicle

Range-extended electric vehicles are powered by an electric motor and plug-in battery, with an auxiliary combustion engine used only to supplement battery charging.



ADVANTAGES



DISADVANTAGES



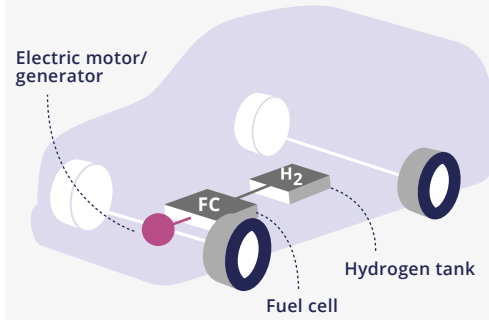
Fuel cell electric vehicles (FCEVs)

FCEVs are also entirely propelled by electricity. In this case, the electrical energy is not stored in a large battery system, but is instead provided by a fuel cell 'stack' that uses hydrogen from an on-board tank combined with oxygen from the air. The main advantages of FCEVs over BEVs are their longer driving ranges and faster refuelling, similar to those of a conventional vehicle. Because of the current size and weight of fuel cell stacks, FCEVs are better suited for medium-sized to large vehicles and longer distances. Fuel cell stack technology is in an earlier stage of development than the technologies described above and few models of FCEVs are currently commercially available. Further technological development is needed for FCEVs to improve their durability, lower the costs and establish a hydrogen fuelling infrastructure, including standalone stations or pumps for hydrogen.

Indicative electric driving range: 160–500 km.

Fuel cell electric vehicle

Fuel cell electric vehicles use a fuel cell to create on-board electricity, generally using compressed hydrogen and oxygen from the air.



ADVANTAGES



HIGHER EFFICIENCY



LOW ENGINE NOISE



ZERO EXHAUST EMISSIONS

DISADVANTAGES



LIMITED
COMMERCIAL AVAILABILITY



LACKING REFUELLING STATIONS



TECHNOLOGICAL COMPLEXITY





How are electric vehicles charged?

The limited driving range of many electric vehicles means that the type of technology used to charge them, and the time it takes, are very important to consumers. Only battery and fuel cell electric vehicles are totally reliant on charging infrastructure; for hybrid vehicles it is not as critical, as they also contain a conventional internal combustion engine.

There are three basic ways to charge an electric vehicle: plug-in charging, battery swapping or wireless charging.

Plug-in charging

Plug-in charging is used by the vast majority of current BEVs and PHEVs in Europe. Vehicles are physically connected to a charging point using a cable and a plug. Plug-in charging can occur wherever charging stations are located: at homes, in public streets or on commercial or private premises.

Electric vehicles can, in general, be charged using normal household sockets, but this is slow because normal domestic sockets provide only a low amount of electric current. It can therefore take approximately eight hours for a typical charge. This can be quite suitable for overnight charging, however. Faster plug-in charging requires specialised infrastructure. To date, most public plug-in stations established at a city, regional or national level offer only normal-speed charging (EAFO, 2016).

Battery swapping

Battery swapping involves replacing a used battery with a fully charged one at a special swapping station. This offers a rapid way of quickly 'recharging' a vehicle. At present, no major providers in Europe offer battery

swapping. A number of barriers have prevented battery-swapping technology from becoming widespread, including the lack of electric vehicle models that support battery swapping, no standard type or size of battery, and the high cost of developing the associated charging and swapping infrastructure.

Wireless charging

Wireless charging, also known as induction charging, does not require a fixed physical connection between the charging facility and the vehicle. Instead, the system creates a localised electromagnetic field around a charging pad, which is activated when an electric vehicle with a corresponding pad is positioned above it. The wireless method currently operates at only a selected few pilot locations and is yet to be used commercially. Examples of inductive charging pilot projects include wireless charging for buses at bus stations in Belgium, Germany, the Netherlands and the United Kingdom, as well as some pilot testing for users of electric cars in Sweden.

The different types of plug-in charging

There are different ways in which battery electric vehicles or PHEVs can be charged via plug-in charging. Four 'modes' of charging technology are commonly

available. Each of them can involve different combinations of power level supplied by the charging station (expressed in kW), types of electric current used (alternating (AC) or direct (DC) current), and plug types.

As electrical power grids provide AC current, and batteries can store only DC current, the electricity provided by the grid to the electric vehicle first needs to be converted. The conversion can be done either by an on-board AC/DC converter inside the electric vehicle or by a converter integrated into the charging point itself. Hence, AC charging is sometimes referred to as 'on-board charging'. DC fast-charging stations have integrated converters, so the charging station itself converts AC electricity from the grid into DC electricity for the electric vehicle.

The power level of the charging source depends on both the voltage and the maximum current of the power supply. This determines how quickly a battery can be charged. The power level of charging points ranges widely, from 3.3 kW to 120 kW. Lower power levels are typical of residential charging points.

Mode 1 (slow charging): allows vehicle charging using common household sockets and cables. It is commonly found in domestic or office buildings. The typical charging power level is 2.3 kW. Household sockets provide AC current.

Mode 2 (slow or semi-fast charging): also uses a non-dedicated socket, but with a special charging cable provided by the car manufacturer. A protection device that is built into the cable offers protection to the electrical installations. It provides AC current.

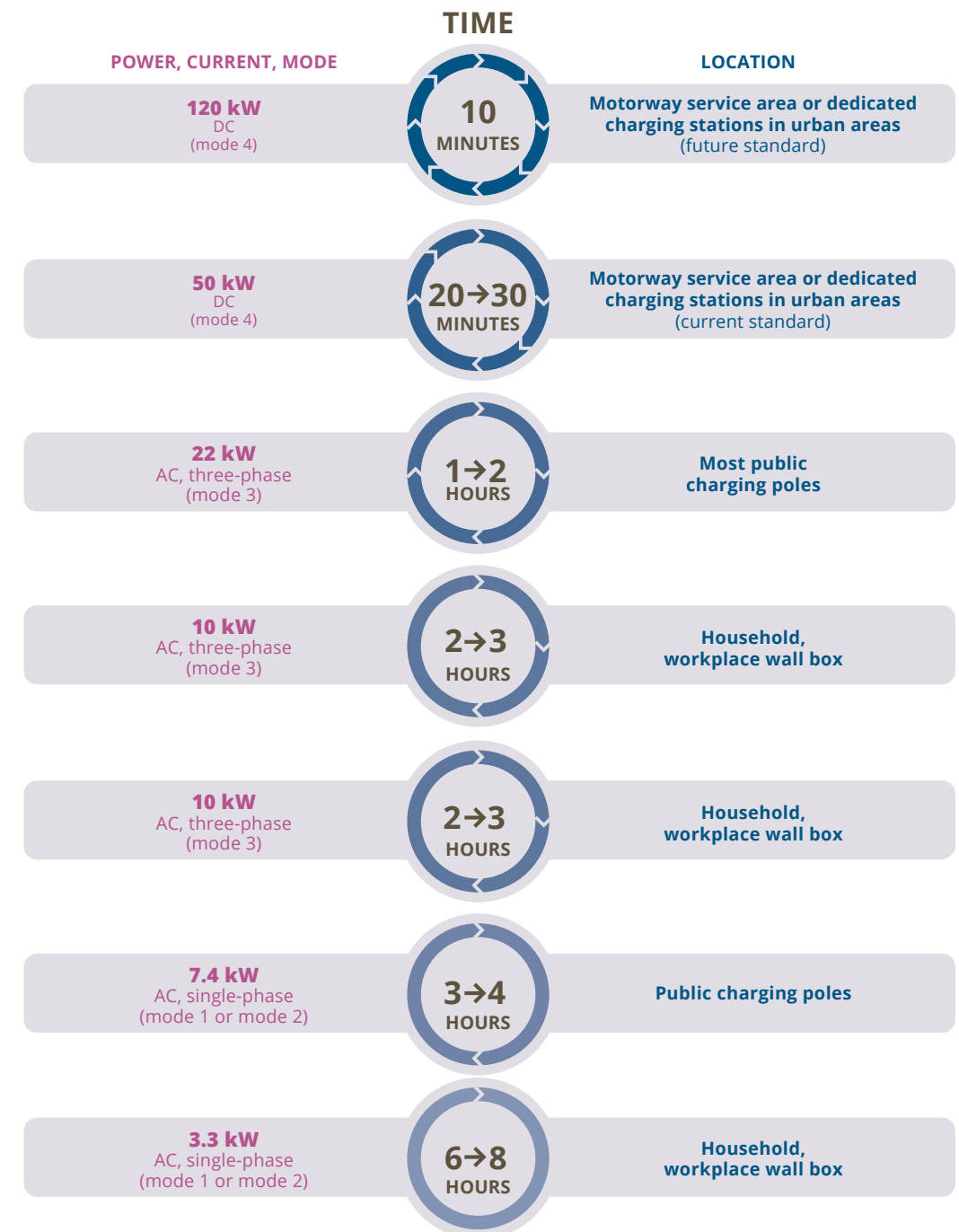
Mode 3 (slow, semi-fast or fast charging): uses a special plug socket and a dedicated circuit to allow charging at higher power levels. The charging can be either via a box fitted to the wall (wall box), commonly used at residential locations, or at a stand-alone pole, often seen in public locations. It uses dedicated charging equipment to ensure safe operation, and provides AC current.

Mode 4 (fast charging): also sometimes referred to 'off-board charging', delivers DC current to the vehicle. An AC/DC converter is located in the charging equipment, instead of inside the vehicle as for the other levels.

One disadvantage of high-power, fast charging is that the stronger currents mean that more electricity is lost during transfer, i.e. the efficiency is lower. Moreover, fast charging can decrease battery lifetime, reducing the number of total charging cycles. Fast DC charging points are also around three times as expensive to install as a simple AC charger, so many users are reluctant to invest in the additional costs. While some new electric vehicle models are provided with a DC charging facility, others require the purchase of an additional charging device (Frenzel et al., 2015; Genovese et al., 2015).

Electricity can be distributed using single-phase or three-phase systems. Households commonly use single-phase power for lighting and powering appliances. It allows only a limited power load. Commercial premises commonly use a three-phase system, as it provides higher power.

Charging times to provide 100 km of battery electric vehicle driving



Source: E-Mobility NSR, 2013.



Where can electric vehicles be charged?

Many people think it is hard to find charging points for electric vehicles. But the number of plug-in stations has increased rapidly in recent years. More than 92 000 public charging positions are now available across Europe (¹).

Charging points for electric vehicles are usually characterised by their degree of accessibility for drivers. The main categories of charging points are generally defined as private, semi-public and public.

Private/domestic charging points

Such charging points are found in homes and business premises. They include dedicated charging boxes or common household plugs. Home charging is a simple option for electric vehicle owners, since no subscription or membership fees are needed to access the charging point. Private charging also occurs when companies install charging points for use by employees on business premises.

Home charging naturally tends to be more common in suburban or rural areas than in urban neighbourhoods, as it requires the car owner to have access to a private garage or be able to connect the electric vehicle to a household socket. In cities, where vehicles are normally parked on public streets or in semi-public car parks, it is more difficult to access a private charging point.

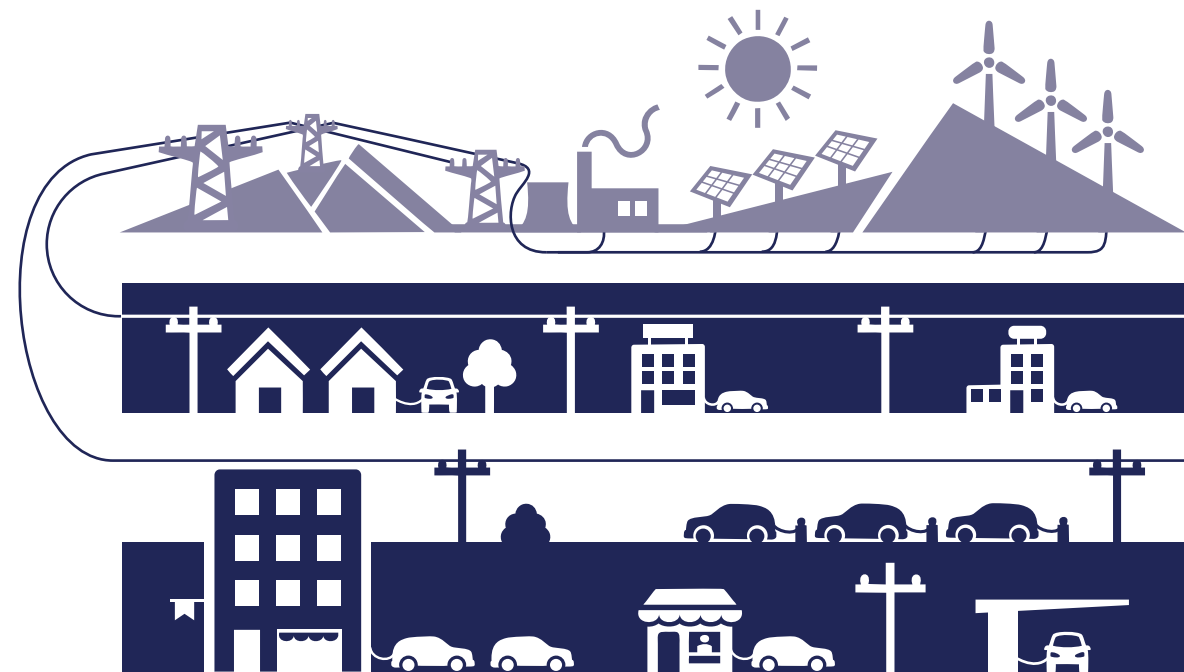
Semi-public charging points

These types of charging points are situated on private ground, but can be accessed by external users. Examples include charging points located in commercial car parks, shopping centres or leisure facilities. Access to these charging points is typically restricted to clients or customers. Operators often regard the charging points as a complimentary service or an opportunity to advertise, so they do not charge customers for the power used. In other cases, the electricity used is included in the customer's parking bill, or in the utilisation fee for car-sharing schemes. Most fast-charging facilities are semi-public and, like conventional petrol stations, are built on private ground but open to all paying users.

Public charging points

Public charging points are usually placed alongside roadside parking spaces or in public car parks. While private or semi-public charging points are often wall boxes, the public infrastructure usually consists of standalone charging poles. In some cases, municipal utilities provide these charging points. However, local authorities are increasingly commissioning commercial providers to facilitate the construction and operation of public charging infrastructure.

(¹) EU-28, Iceland, Norway, Switzerland and Turkey (EAFU, 2016).



Paying for electric vehicle charging

In some cities, public charging points are free for electric vehicle users. Tesla also offers a network of fast-charging points across Europe for free use by owners of certain models. Such free charging points are designed to provide an early incentive for consumers to purchase electric vehicles. In the longer term, if electric vehicles become more common, free charging for electric vehicles is likely to disappear.

Elsewhere, a wide range of payment systems are used at charging points. At public or semi-public charging points, different payment and identification methods are possible. Users are often identified by means of a smart card and are subsequently charged for the actual power used. This can mean that each user needs to register and keep several smart cards from different operators in order to access enough charging points. In other cases, electricity suppliers register specific vehicles and provide each vehicle with a digital

identification key. Registered vehicles are then recognised at charging points without the user needing a card. This system is known as 'plug and charge'.

Other technical options for user identification include phone hotlines, text messages, 'smart cables' that have an integrated SIM card, PIN numbers and even physical keys. Sometimes customers can pay directly at the charging point (with a bank card or cash), or in combination with a proof for paying car parking fees. Both identification and payment can increasingly be done using smartphone apps.

Several initiatives have tried to simplify the variety of payment options used in Europe. They aim to make an ever-greater number of charging points available for all electric vehicle users by forming consortia of charging infrastructure providers and facilitating 'eRoaming'. That does away with the need for owners to always hold several smart cards from different operators. At the EU level, the Alternative Fuels Infrastructure Directive (EU, 2014) made ad-hoc access to charging stations mandatory as well as requiring 'reasonable, easily and clearly comparable, transparent and non-discriminatory' prices.



Developing charging point infrastructure in Europe

What is the 'ideal' number of charging points that should be achieved in the EU, how should they be distributed and on what timeline? The answers to these questions depend a great deal on future developments in electric vehicle technology and markets. Electric vehicle sales will not increase if the current charging infrastructure remains static. However, it also makes little sense to expand charging infrastructure significantly without knowing how individual mobility in general, and especially the electric vehicles market, will develop in the future. Ideally, both the vehicle market and the infrastructure should grow simultaneously.

The Alternative Fuels Infrastructure Directive (EU, 2014) provides one estimate of the desired proportion of charging points to electric vehicle numbers: at least one public charging point for every 10 vehicles, always taking into account new developments in vehicle, battery and charging infrastructure technology and assuming that most private electric vehicle owners install their own charging points.

The recently published European strategy for low-emission mobility further highlights the importance of publicly available electric recharging points. In order to achieve mass acceptance and deployment of electric vehicles, it recognises that charging and maintenance infrastructure needs to become widely available throughout Europe (EC, 2016).

There are two general approaches to building up charging infrastructure. The first involves developing a complete electric vehicle charging network in one step. The second is incremental growth, based on enlarging the infrastructure as user demands increase over time.

If sufficient funding is available, the first approach can help promote a rapid uptake of electric vehicles. In reality, the incremental approach is more common, as public funding is often limited and it can be difficult to justify public investment in charging infrastructure without matching public demand. However, without a large charging infrastructure network, consumers will hesitate to buy electric vehicles.

Besides the number and distribution, the types of charging points to be made available to electric vehicle users have to be decided. Several European studies have concluded that, in most scenarios, it is possible to ensure everyday mobility using only common electric vehicles charging overnight at home. Such guidance is necessarily simplified. It focuses on everyday mobility in urban areas and disregards long-distance trips.

Consumers remain concerned that electric vehicles have a limited range. These concerns can be allayed by installing infrastructure that recharges vehicle batteries quickly, to accommodate long-distance trips.

The Estonian electromobility programme (ELMO)



In 2011, Estonia launched a national electric car mobility system, ELMO. This programme promotes electric cars for emission-free personal transport, to achieve healthier environments, energy efficiency and fuel independence.

In the first stages of the project, the Ministry of Social Affairs purchased approximately 500 Mitsubishi electric cars to start building up an electric car pool. They financed them by selling national CO₂ emission credits. By November 2013, a total of 165 fast chargers had been installed in Estonia, covering the entire country. Today, there are more than 1 100 battery electric vehicles on the Estonian traffic register, about 500 of them used by various state authorities.

Until 2014, the government had also issued grants for 50 % of the cost of a new electric vehicle. The average price of an electric vehicle in Europe is EUR 30 000, and under the scheme it was possible for consumers to save up to EUR 18 000. In addition, new electric vehicle owners could apply for a EUR 1 000 grant to cover the costs of installing a home charging station.

The goal of the programme is to speed up the commissioning of electric cars in Estonia, and help the state achieve its goal of increasing the use of renewable energy by 2020.

To safeguard the environmental benefits of the ELMO programme, including reducing harmful GHG emissions from conventional fossil energy sources, all electric vehicles must consume only electricity generated from renewable energy sources. A 'Guarantee of Origin' scheme ensures this. There are also certain practical benefits for electric vehicle owners, including free parking in a municipal car parks, and the use of bus lanes.

Source: ELMO, 2016.

Drawbacks of the expansion of fast-charging networks

There are some drawbacks of fast charging and the development of fast-charging networks. Frequent fast charging may reduce the battery's life expectancy. In contrast, frequent and incomplete discharging and recharging using slow charging does not harm the battery to the same extent. Most manufacturers indeed recommend running the battery between 10 % and 80 % charged. Moreover, the average cost of a typical DC fast-charging point is about three times as high as a normal AC charging point.

Many available BEVs, and especially most PHEV models, currently do not support fast charging, or they feature it only as an expensive optional extra. For most users, slow charging is often sufficient, as most consumer journeys are short trips only, so electric vehicles usually return to the charging point with quite a lot of charge in the battery (EC, 2012; Gautama et al., 2015; KIT, 2015). For longer trips, however, a network that can be used for ad hoc fast charging can help resolve consumer concerns about the limited range of electric vehicles.

The charging infrastructure in Europe

In most European countries there are only a few thousand public charging points, and they are for slow charging. Such public charging points are typically installed by public authorities, utilities, electric vehicle manufacturers or other companies. In Europe, the Netherlands leads the way with a network of over 23 000 public charging positions in 2016. Other countries with large numbers of

public charging points include Germany (more than 14 000), France (more than 13 000), the United Kingdom (around 11 500) and Norway (more than 7 600). The lowest numbers of charging positions (fewer than 40) are in Bulgaria, Cyprus, Iceland and Lithuania (EAFO, 2016). Some countries are slowing down the installation of new public slow-charging points, with more focus shifting to the expansion of fast-charging infrastructure.

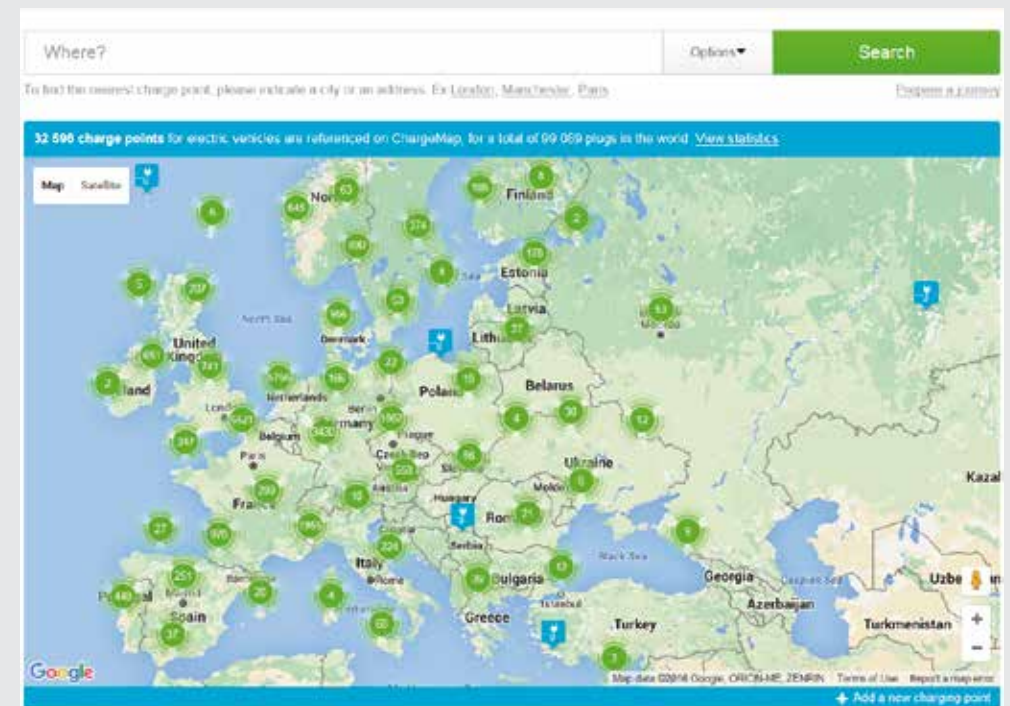
The European Union established the Trans-European Transport Network (TEN-T) programme to support the construction and upgrading of transport infrastructure across the region. On infrastructure for electric vehicles, the programme has invested in various projects including the pilot deployment of 115 high-power recharging points on central European roads, to help enable the long-distance driving of electric vehicles and promote sustainable transport (TEN-T, 2016).

Several years ago, proposals were put forward to include charging point targets for each EU Member State in the Alternative Fuels Infrastructure Directive (EU, 2014). This would have resulted in up to 8 million charging points in the EU by 2020, with at least 800 000 available to the general public. However, these targets were dropped during negotiation of the final text of the directive. Instead, governments were required to design national action plans on charging point infrastructure and to install an 'appropriate number of electric recharging points accessible to the public' by the end of 2020 (EU, 2014).

Web services and smartphone apps to find charging points

A growing number of websites and smartphone apps offer real-time services that show drivers the locations and availability of charging points in their cities. The types of charging point network information they provide can vary. Some applications provide information only for the charging points associated with a single charging provider or network. Other third party applications endeavour to present a complete picture of all charging sites available in a given locality.

ChargeMap is a community-based service aiming to list all the public or semi-public charging points for electric vehicles available worldwide. All charging points, made for slow or fast charge, are listed on the website and on its mobile version (chargemap.com).



Source: chargemap.com, accessed July 2016.



Other types of electric road vehicles

Many other types of vehicles than passenger cars can run on electricity. They include railway engines, water-borne ferries, ships and small leisure craft, as well as underwater vessels. On the road, electric bicycles, vans and buses are increasingly offering alternatives to conventional technologies.

Electric bicycles or 'e-bikes'

Electric bicycles or 'e-bikes' is a general term used for power-assisted bicycles, i.e. for pedelecs and self-powered e-bikes. Pedelecs operate in much the same way as conventional bicycles. They have physical pedals, with optional assistance from an electric motor. Self-powered e-bikes also have electric motors but can be propelled from battery-power alone (UBA, 2014).

Electric-powered bicycles have a battery pack and a motor to store and use the electricity. The handle bar usually includes a user control to brake and adjust the speed. The motor can typically support speeds of up to 25 km/h. The first e-bikes tended to use cheaper, heavy lead-acid batteries, but most e-bikes now for sale in Europe generally use lighter, more efficient but more expensive lithium-ion batteries.

Electric bikes have obvious advantages over conventional bicycles and other means of transport. Although heavier than most normal bicycles, they allow cyclists to overcome challenges such as steep hills and long distances. They are particularly ideal for enabling people who would not normally cycle to consider cycling as a possible means of

transport. Several public bicycle-sharing schemes in Europe's cities use some type of e-bike.

Between 2006 and 2014, there was a steady growth of electric bikes sales in the EU. It is estimated that around 1 325 000 e-bikes were sold in the EU in 2014, almost 14 times as many as in 2006. Around half of the e-bikes sold in Europe are imported, and of these, almost 80 % originate from China (BikeEurope, 2015). Strong growth has occurred in several countries over recent years, driven by wider availability and somewhat falling prices. Still, e-bikes are on average more expensive than comparable conventional bicycles. France recorded 2014's biggest increase in e-bike sales: 77 500 electric bicycles were sold, 37 % more than the previous year. Germany, however, has the largest e-bike market in Europe, with total sales of 480 000 in 2014. Other countries reporting strong growth in the numbers of e-bikes include the Netherlands — currently the EU's second-biggest e-bike market — Austria, Belgium, Switzerland and the United Kingdom.

Mopeds and e-scooters also run on an electric motor and need no pedalling. They usually allow higher speeds, 45 km/h or more, but require registration and a driving licence in some countries.



Light commercial vehicles (vans)

Electric vans are not yet widely available. However manufacturers are slowly increasing the number of models they offer. Electric vans are an increasingly credible and attractive alternative to conventional vehicles, particularly for those businesses that use vans for regular short-distance urban deliveries.

Small vans use the same types of electric vehicle technologies as described earlier: battery electric, PHEVs etc. Vans weighing more than two tonnes need larger battery capacities than those for medium-sized passenger cars.

Heavy-duty vehicles (HDVs)

HDVs have specific load-bearing and distance requirements for the transport of goods. They are heavy, meaning battery capacities need to be very high to cope with both heavy loads and long distances. For long-distance vehicles, battery electric driving is presently not a feasible option because the additional costs are high and a battery of the required capacity would be heavy. Only a very small number of heavy-duty electric vehicles are on the market, and they weigh no more than 18 tonnes. One example is the 18-tonne Swiss 'eForce one', which has a battery weight of 2.6 tonnes and an electric driving range of 300 km.

Using electric heavy-duty vehicles for regional distribution mainly depends on future trends in fuel prices and the implementation of low- or zero-emission zones in cities. The further technological development of batteries and the need to reduce battery costs are important factors for the wider use of such vehicles.

Electric buses

Electric buses have great potential for future use in cities. Electric trams have been used for decades and are a proven technology, but the infrastructure costs are relatively high and the overhead cabling needs maintenance.

Electric buses using high-capacity batteries are currently in use or under testing in a number of cities. There are more than 500 battery electric buses in the EU-28. The highest numbers are in Austria, Belgium and the Netherlands (EAFO, 2016). Plug-in hybrid electric buses offer more flexibility than battery electric buses and are increasingly being used in many cities across Europe including Budapest, Copenhagen, London, Oslo and Warsaw. Both battery electric and hybrid buses are more expensive than conventional buses, and can also suffer from temperature-sensitive energy consumption. Certain electric bus models can be charged overnight, while others, with smaller batteries, must also be charged during the day.





How environmentally friendly are electric vehicles?

Understanding the environmental impacts of any product requires looking at its entire lifecycle: from the extraction of raw materials, to the pollution generated during its manufacture, operation and disposal, through to the impacts of the residual waste remaining after disposal or recycling. For an electric vehicle, the source of the electricity used during its operation plays a large role in the overall environmental impacts.

Production

Production of electric vehicles is typically more energy-intensive than conventional vehicle manufacture. It needs approximately 70 % more primary energy to make BEVs than conventional vehicles, mainly for the electric engine systems and batteries (EC, 2015a). These higher energy requirements can lead to higher emissions of GHGs and associated air pollutants, depending on the source of energy used.

Their manufacture also requires a number of different rare raw materials, especially for the magnets used in the electric motor and in the batteries. Many of these metals are considered 'critical': they are necessary if electric vehicle manufacture is to grow, but it is not certain that they will be available in sufficient quantities for such future market demands. Furthermore, many of these rare raw materials are either not available within Europe at all or not available in large quantities, so European vehicle manufactures have to rely on obtaining them from other parts of the world.

The lithium included in lithium-ion batteries is not itself considered a critical metal. Global supplies are ample, although its price has already risen in recent years as demand for battery manufacture has increased. However, batteries can also include a number of other, relatively rare, elements including cobalt, lanthanum and nickel. In particular, the production processes for cobalt and nickel present potential environmental and health hazards. Cadmium, previously an important but toxic constituent of rechargeable nickel-cadmium batteries, is not used in modern lithium-ion batteries.

The high-powered magnets included in electric motors often contain rare earth elements that are considered critical metals, including neodymium, dysprosium, samarium and cobalt (EC, 2014). Future demand for such critical materials will increase significantly as the electric vehicle market develops. One open question is if the limited availability of these metals on the global markets may restrict the rate of electric vehicle manufacture in future.



In-use

Battery electric vehicles, unlike conventional and electric hybrid vehicles, have no exhaust emissions. The source of the electricity needed to charge electric batteries — nuclear power plants, fossil fuels or renewables — plays a large role in determining the overall emissions of an electric vehicle throughout its lifecycle.

During their lifetime, battery electric vehicles are only as clean as their source of electricity. Any future significant growth in the numbers of electric vehicles will lead to a greater demand for electricity, and will require both adequate generation capacity as well as the capability of electricity grids to handle the additional amounts of electricity generated. In this case, emissions from the road transport sector are in effect displaced to the power generation sector. The emissions that will occur from electricity generation depend on the overall fuel mix used in that sector (within a country or region), and, if the fuel mix varies throughout the day, on the time when vehicles are charged.

Even when running on power from renewable sources, however, electric vehicles are not zero-emission vehicles. They still generate non-exhaust emissions of particulate matter for example, due to wear of tyres, brakes and roads.

The environmental impact of PHEVs also depends on their operation mode. The all-electric mode results in effectively zero exhaust emissions, but using only the conventional engine can lead to emission levels higher than those of an equivalently

sized conventional vehicle because the batteries make the vehicle heavier.

The future road transport and electric power sectors will become more closely linked if there is wide uptake of electric vehicles in the EU. Recent findings from the EEA show that, if a hypothetical 80 % of cars in 2050 were electric, an additional 150 GW of additional electricity generation capacity would be needed across the EU (assuming no reduction of demand from other sectors) (EEA, 2016a).

The increase in electric cars leads to a reduction in GHGs (CO₂) and local air pollutant emissions (NO_x, SO₂ and PM) in the transport sector. Depending on the source of electricity production, these positive effects are (partially) offset by additional emissions in the energy sector due to the additional electricity demand. The impact of local air pollutant emissions from electric vehicles and emissions from power generation cannot directly be compared as the exposure is different for both sectors. Emissions from road transport occur at ground level and generally in areas where people live and work, such as in cities and towns, so many of the population are exposed to them. In contrast, power stations are generally outside cities, in less populated areas.

The EEA work shows that, assuming the extra electricity demand is supplied by the energy mix projected for 2050 by the EU Reference Scenario 2013 (EC, 2013), future emissions of both GHGs (CO₂) and air pollutants (NO_x and PM) would be lower, producing a clear net overall environmental benefit.

The hypothetical average 80 % electric car penetration across the EU in 2050 will reduce GHGs by 255 Mt CO₂ in comparison to the EU Reference Scenario (EC, 2013), which assumes an 8 % electric car fleet in that year. Similarly, large NO_x and PM emission reductions in the transport sector and low additional emissions in the power sector would result in clear benefits for NO_x and PM. However, the increased use of coal in power generation may result in additional SO₂ emissions, which exceed the emission reduction achieved in passenger road transport by a factor of five (EEA, 2016a).

End-of-life

End-of-life vehicles create many millions of tonnes of waste each year in the EU. Existing EU legislation, including the EU Directive on end-of-life vehicles (EU, 2000), already aims to reduce waste and encourage recycling of scrap vehicles. The large batteries and additional electrical components available for recycling, including the electric motor and its magnets, distinguish electric vehicles from conventional vehicles.

Recycling rates depend on the materials used in production. Some can be reclaimed and recycled easily (pure alloys), others are harder to reclaim or their ability to be reused is largely unknown. High recycling rates of lithium-ion batteries are for example technically possible. However, there is no large scale recovery in place yet. Lithium-ion batteries also contain fewer hazardous materials, such as cadmium or lead, than other types of batteries, and therefore are generally considered safe for incinerators and landfill.

Many manufacturers aim to establish a 'closed loop' recycling system, manufacturing battery cells, assembling them into battery packs, installing them in vehicles and finally recycling them into raw materials for future use.

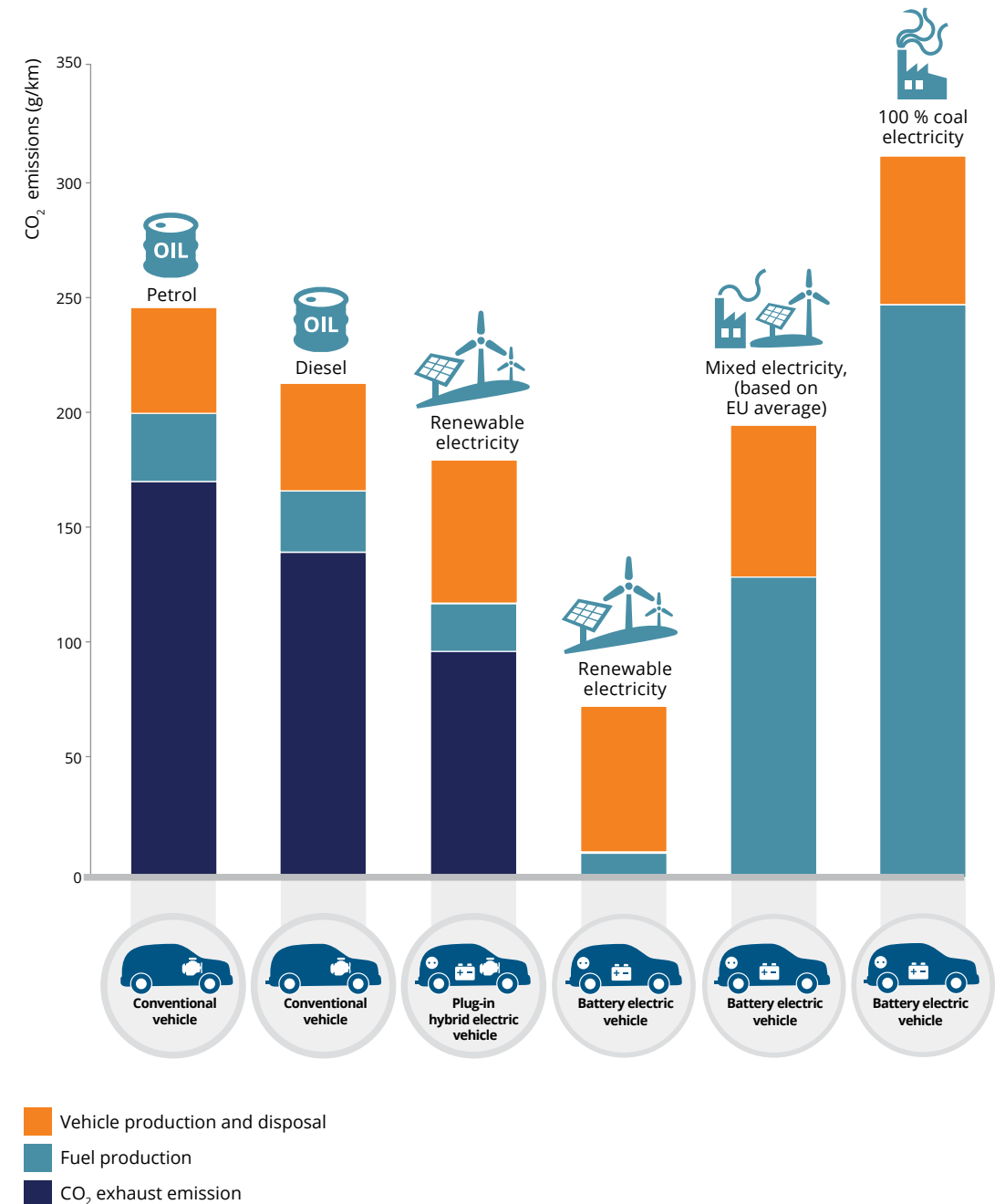
Larger-scale recycling of electric vehicle batteries is expected to be developed in the near future. However, mining lithium generally remains cheaper because lithium accounts for only up to 10 % of current battery manufacturing costs. It is a similar situation for other common battery components such as cobalt, iron and nickel. Presently, therefore, end-of-life recovery and recycling rates of rare materials in batteries remain low, below 1 % globally (UNEP, 2011). On the other hand, in the longer term the growth of the electric vehicle market could reduce demand for the platinum, palladium and rhodium currently used in conventional vehicle exhaust catalysts, although hybrid technology is still reliant on these catalysts.

Overall

The reduced emissions during the electric vehicle's lifetime are considered to outweigh the environmental effects of the production and end-of-life phases. Electric vehicles can therefore significantly reduce the adverse environmental effects of conventional passenger vehicles, as long as the electricity is from renewable sources.

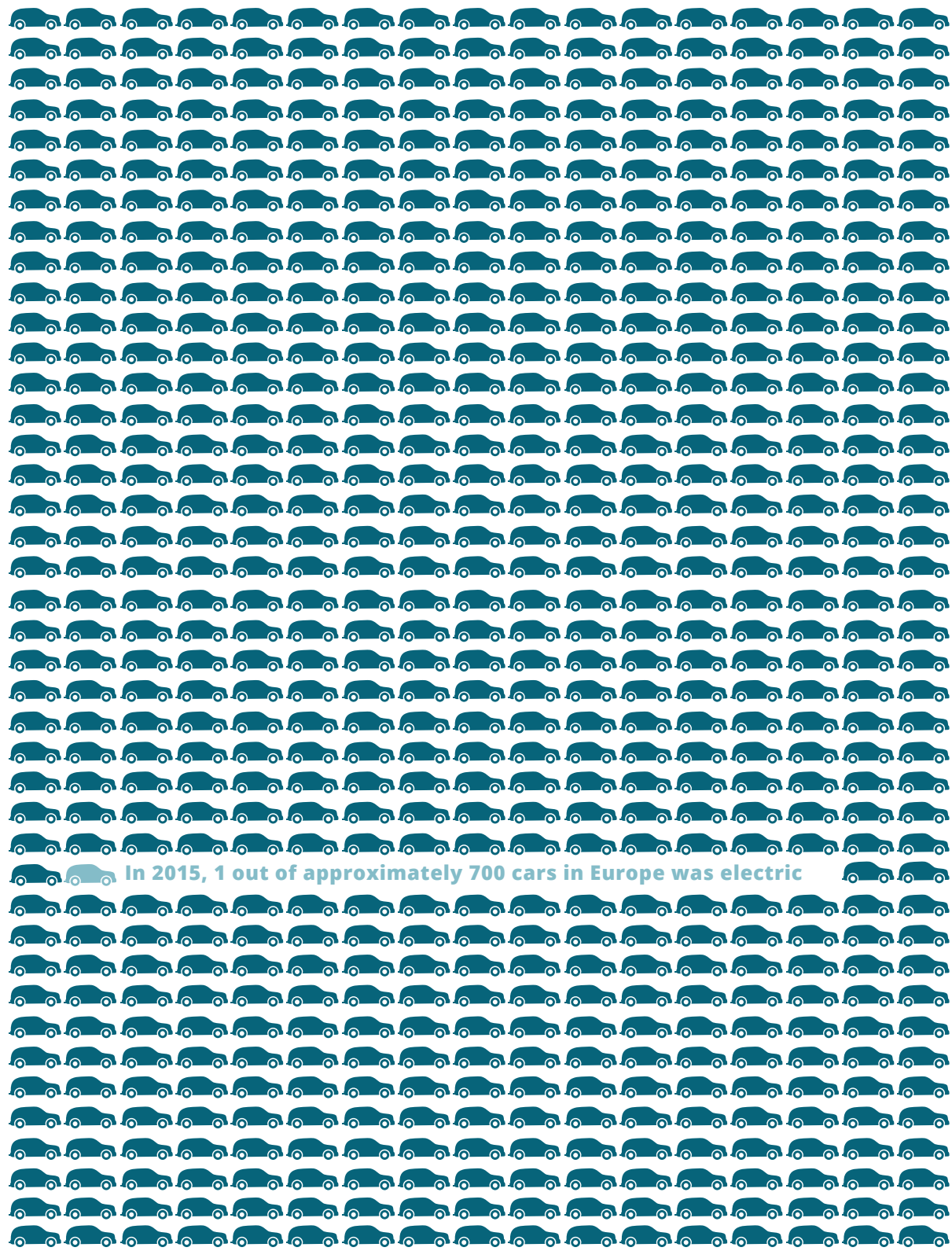
Illustrating this, a recent Dutch study compared relative emissions across the lifetime of different types of vehicles, from their manufacture to disposal (TNO, 2015). The study clearly showed the differences in estimated lifecycle emissions for mid-class conventional, PHEV and BEV, and the importance that the source of electricity, ranging from 100 % renewable through to a hypothetical 'worst-case' 100 % coal combustion, has on these.

Range of life-cycle CO₂ emissions for different vehicle and fuel types



Note: The values are estimated for an average mid-class vehicle, based on 220 000 km.

Source: TNO, 2015; authors' own calculations.



How many new electric vehicles are sold in Europe each year?

There are more and more vehicles on Europe's roads. While electric passenger vehicle sales have increased rapidly over past years, they represented just 1.2 % of all new cars sold in the EU in 2015. In all, approximately 0.15 % of all passenger cars on European roads are electric. Like passenger vehicles, sales of electric vans also made up a very small fraction of total EU sales in 2015.

Electric passenger vehicle sales

Conventional (non-plug-in) hybrid electric vehicles have been available in Europe for almost two decades. Unfortunately, past sales numbers for these types of vehicle are not easily available from official EU statistics, as national authorities have generally categorised them simply as petrol or diesel vehicles.

Of the other types of electric vehicles, BEVs were the first type widely marketed in the EU, although sales in early years were very low. In 2010, fewer than 700 BEVs were sold across the EU. PHEVs have been commercially available since around 2011. Again, statistics for plug-in hybrid sales in those early years are uncertain, as many Member State authorities have categorised them as petrol, diesel or battery electric vehicles.

From 2013 onwards, petrol and diesel plug-in hybrid models became significantly more popular as both the range of vehicle models available for consumers increased and more governments promoted various subsidies to encourage electric vehicle ownership. In

that year, there were just over 49 000 electric vehicles sold in the EU, of which half were BEVs, and half PHEVs.

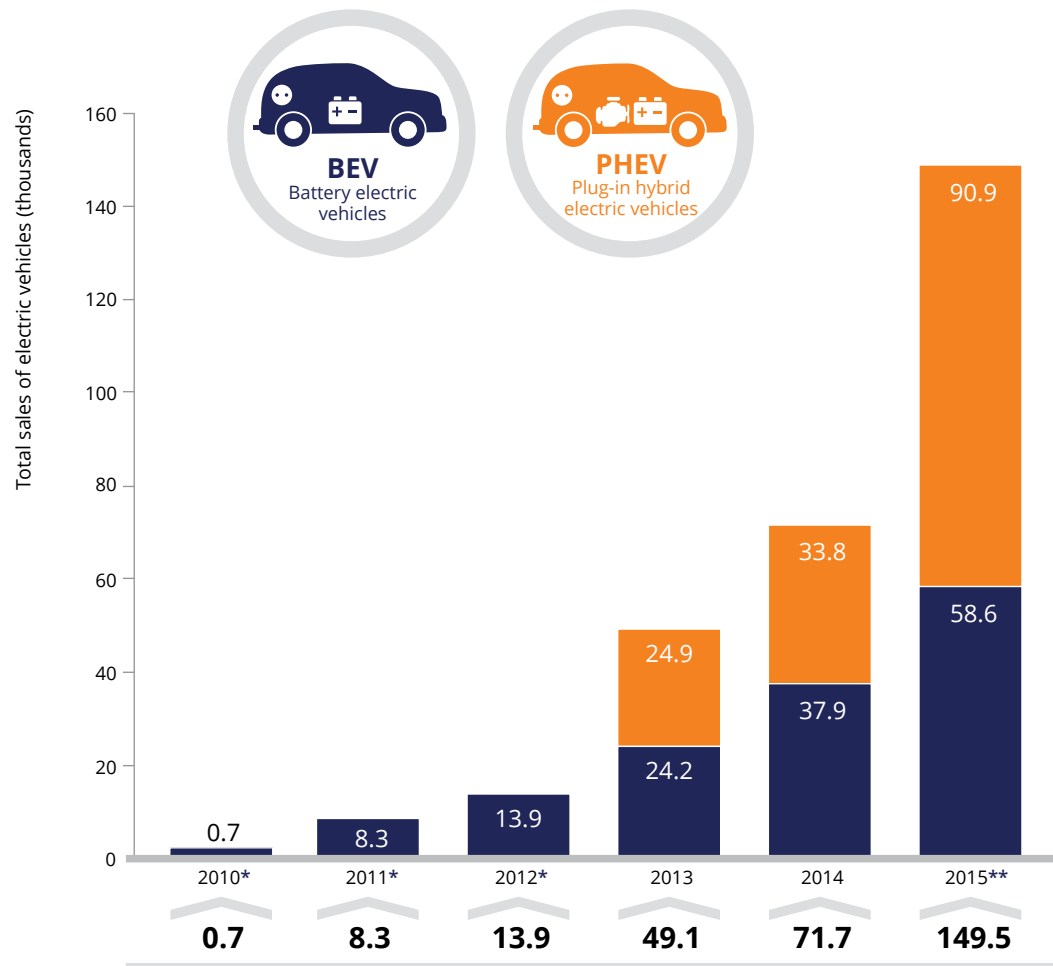
The number of electric vehicles sold has increased steeply in each year since. The latest preliminary data for 2015 indicate that almost 150 000 new plug-in hybrid and battery electric vehicles were sold in the EU that year (EEA, 2016b; EAFO, 2016). Almost 40 % of these were BEVs. Collectively, just six Member States account for almost 90 % of all electric vehicle sales: the Netherlands, the United Kingdom, Germany, France, Sweden and Denmark.

The largest numbers of BEV sales within the EU-28 were recorded in France (more than 17 650 vehicles), Germany (more than 12 350 vehicles) and the United Kingdom (more than 9 900 vehicles). The largest numbers of PHEV sales were recorded in the Netherlands (more than 41 000 vehicles) and the United Kingdom (more than 18 800 vehicles).

In Latvia, Lithuania, Malta and Romania, fewer than 50 BEVs and PHEVs were sold in 2015. None were sold in Bulgaria and Cyprus.

Source: EEA, 2016b; EAFO, 2016; EC, 2015b.

Total sales of electric vehicles in the EU-28



Electric vehicles still make up only a small fraction of all new vehicles sold in the EU, just 1.2 % in 2015. In certain countries, however, the relative proportion of PHEVs and BEVs among new vehicles is much higher. For example, it is approximately 10 % in the Netherlands. In all, approximately 0.15 % of all passenger cars on European roads are electric.

Outside the EU, a clear frontrunner in terms of high sales is Norway, where 22.5 % of all new cars sold in 2015 were electric. Almost 34 000 new electric vehicles were sold, of which 77 % were BEVs (EAFO, 2016).

Electric van sales

Around 0.5 % of new vans sold in the EU in 2015 were battery electric vans. Sales have increased over recent years, by 15 % per year on average. The total number of electric vans sold rose from 5 700 in 2012 to more than 8 500 in 2015.

Most battery electric vans are sold in France, where around 3 900 were sold in 2015, followed by Germany (around 950), the United Kingdom (800), Spain (500) and Italy (450). However, in most countries very few are sold; in each of 13 other Member States fewer than 10 battery electric vans were sold in 2015. One main reason for the low sales is a lack of available models for consumers to choose from.

Statistics on electric vehicle sales in Europe

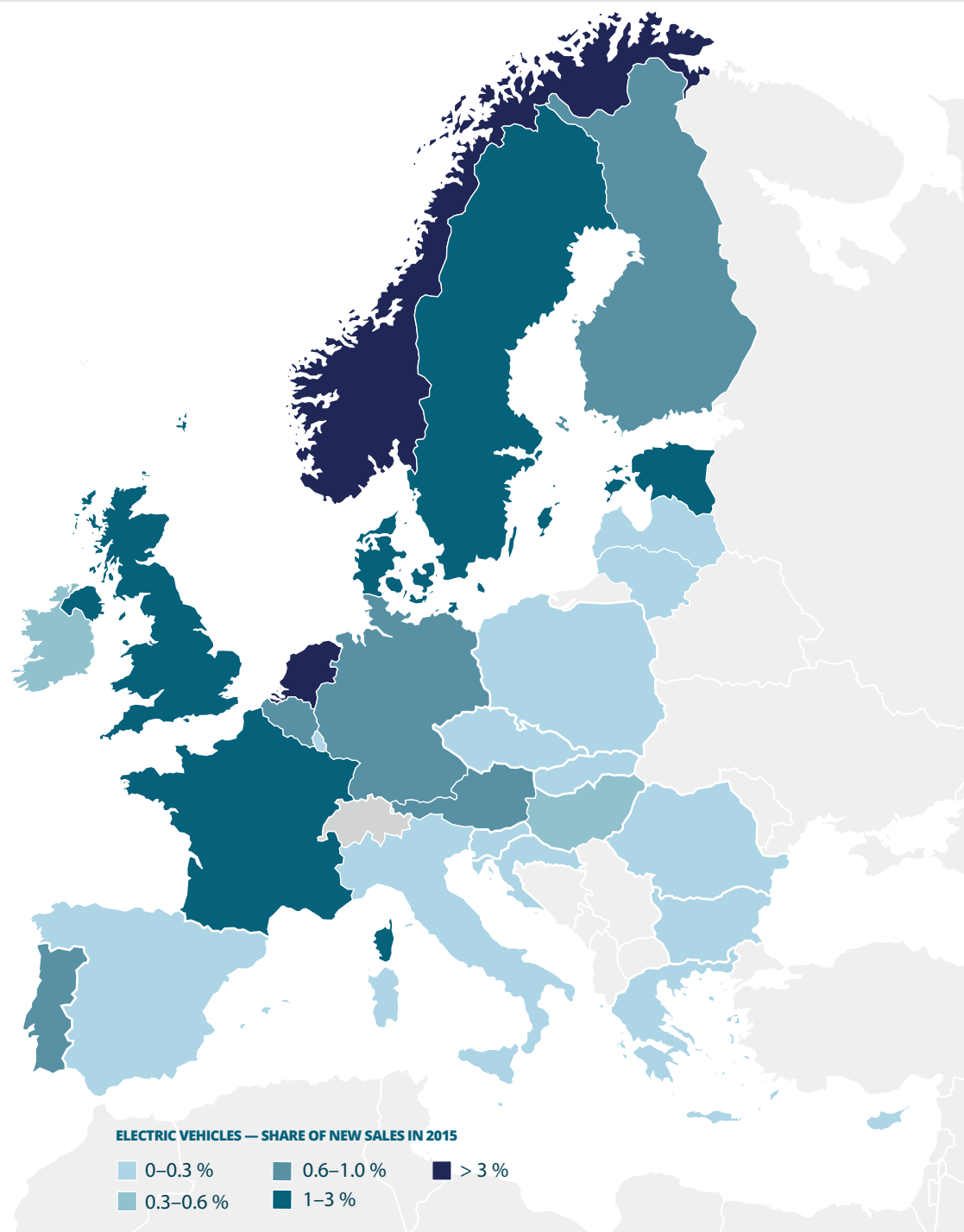
The EEA's information on annual sales of passenger cars and vans comes from official data reported by Member States and vehicle manufacturers. These are governed by two complementary regulations: Regulation (EC) No 443/2009 (EU, 2009a) setting emission performance standards for new passenger cars and Regulation (EC) No 510/2011 (EU, 2011) setting emission performance standards for new light commercial vehicles. Available on the EEA website, each dataset includes information on the number and models of new vehicles registered each year, as well as information on their respective CO₂ emissions and masses.

Many other organisations also provide information on annual or monthly vehicle sales. They include national vehicle and statistical agencies, as well as industry associations such as the European Automobile Manufacturers' Association (ACEA) and the European Alternative Fuels Observatory (EAFO).

Note: * In 2010, 2011 and 2012, only statistics for BEVs are available. ** The data for 2015 are provisional.

Source: EEA, 2016b; EAFO, 2016.

Electric vehicles — share of new sales in 2015



Source: EEA, 2016b; EAFO, 2016.

Changing trends in the electric vehicle market

Following the initial development of conventional (non-plug-in) hybrid electric vehicles, advances in battery technology has seen manufacturers starting to promote first BEVs and then the various plug-in hybrid technologies in more recent years.

Manufacturers have followed different approaches to developing electric vehicle models. The so-called 'conversion' approach adds the new technology (i.e. an electric motor and a battery) to an existing model. In contrast, the 'purpose' approach involves a new vehicle design, arguably allowing manufacturers to take greater advantage of the new technology in designing and optimising the vehicle performance.

Still, relatively few electric vehicle are sold in Europe, and fewer models are available to consumers than for conventional vehicles. However, almost every car manufacturer has now included electric vehicles in its range, with each producer launching at least one new plug-in hybrid electric model each year. It is expected that more affordable electric vehicles will be produced in the future (ICCT, 2015).

Small and medium-sized BEVs, as well as medium-sized and large PHEVs, dominate the market. Purchase prices vary significantly between different models, depending on electric driving range, vehicle size and brand.

The consumer demand for BEVs or PHEVs also varies between countries, depending on the various incentives or purchasing subsidies that governments offer. Norway, for example, has seen a high demand for BEVs in recent years, although recent changes to Norwegian electric vehicle subsidies saw a strong shift in 2015 towards PHEVs. In the Netherlands, many more consumers purchase PHEVs than BEVs, which again is a reflection of the specific incentives in place (ICCT, 2015).

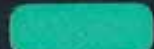
The broader development of the electric vehicle market in Europe depends on several factors, including how effective the incentives in EU emission regulations are in getting manufacturers to reduce CO₂ emissions; the financial incentives that countries offer for purchasing and operating them; fuel prices; battery costs; infrastructure; and general travel behaviour. In the 2011 White Paper on Transport, the European Commission set a target of halving the use of conventionally fuelled cars in urban transport by 2030 and phasing them out in cities by 2050. Such objectives can combine with EU-wide environmental regulations to contribute to shaping the electric vehicle market in the short and medium terms. More PHEVs than BEVs and REEVs, are due to be produced in the next few years (McKinsey, 2014). However, PHEVs are often regarded as a transition technology. Sales of BEVs are expected to be higher in the longer term.



CIRCONTROL



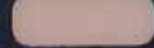
READY



CHARGE



FAULT



What factors may concern potential purchasers of electric vehicles?

Consumers can today choose from an ever-increasing number of electric vehicle models offering many environmental benefits. Even so, sales of electric vehicles still lag far behind those of conventional vehicles. There are a number of reasons why consumers may be reluctant to purchase an electric vehicle.

As noted in the introduction to this report, simply replacing conventional vehicles with electric vehicles will not address Europe's need to move toward a more sustainable transport system. Problems such as congestion and pressure on the road infrastructure will remain. To make the road transport sector sustainable in the long term, behaviour will need to change. This includes shifting towards more non-motorised and/or public transport. Nevertheless, in the short and medium terms, wider use of electric vehicles is one way to help move to a more sustainable transport system.

For a number of reasons, many consumers do not see electric vehicles as a credible transport option. These include cost, user requirements, limited information and technological uncertainty (in comparison with the more familiar conventional vehicle technologies), as well as certain country-specific factors.

Higher current costs

In the absence of national subsidies, a passenger electric vehicle can be up to EUR 10 000 more expensive than a comparable conventional vehicle (Hacker et al., 2015). In other words, consumers currently have to pay a premium of up to 100 % for smaller vehicles. This difference is mainly because of the battery system of electric vehicles. Several studies have concluded that cost is the main reason more people do not buy electric vehicles. Private users typically also focus more on purchase price, while largely ignoring or underestimating energy prices and other associated running costs (Vogt and Bongard, 2015). Costs may, however, decrease in the future thanks to economies of scale in manufacturing.

Electric vehicles can, however, need less maintenance than conventional vehicles. Motor oil, filter material, brake linings and other parts need to be replaced less frequently, if at all. However, other costs can increase. For example, insurance costs can be higher. Providers tend to require

Total cost of ownership

Total cost of ownership (TCO) is a measure designed to include all costs of owning a car from when it is purchased (financing, fees and taxes) to the time it is sold or passed on (residual value), including operating costs (fuel, insurance, repairs, fees and taxes, and maintenance).

The higher purchase price of electric vehicles is typically partly offset by lower fuel costs. If the electric vehicle is used frequently, then its lower running costs are even more favourable. Estimates of the difference in TCO between electric vehicles and conventional vehicles vary widely, from about EUR 5 000 to EUR 20 000 per vehicle (over four years with an annual mileage of 20 000 km), depending on country, type of electric vehicle model, fuel prices and other variables (McKinsey, 2014).

A number of country-specific factors can, however, further improve TCO for electric vehicles. These include tax exemptions, reduced electricity prices and proportionally smaller costs for charging infrastructure (Hacker et al., 2015).

Electric vehicles can deliver additional advantages if combined with measures such as:

- smart charging, leading to potentially lower electricity prices for consumers;
- car sharing;
- intelligent fleet management.

TCO is clearly affected by changes in government policies such as withdrawing incentives for electric vehicles or, conversely, higher taxes on conventional fossil fuels in the road transport sector.

higher premiums because electric vehicles cost more to repair or replace if they are badly damaged.

Another barrier concerns uncertainty about consumer incentives. If drivers expect that current practical incentives encouraging electric vehicle ownership, such as free city parking and charging, will be removed in the near future, then it can affect purchasing decisions. Commercial operators of electric vehicles also mention several legal uncertainties, e.g. fiscal issues and legitimacy

concerning accounting for use of electricity and private use of company cars.

Availability and choice of models

All major car manufacturers have now started producing battery or plug-in hybrid electric vehicles. More than 30 models are currently available in Europe. But that is a small number compared with the number of available conventional car models, so consumers do not have as great a choice of

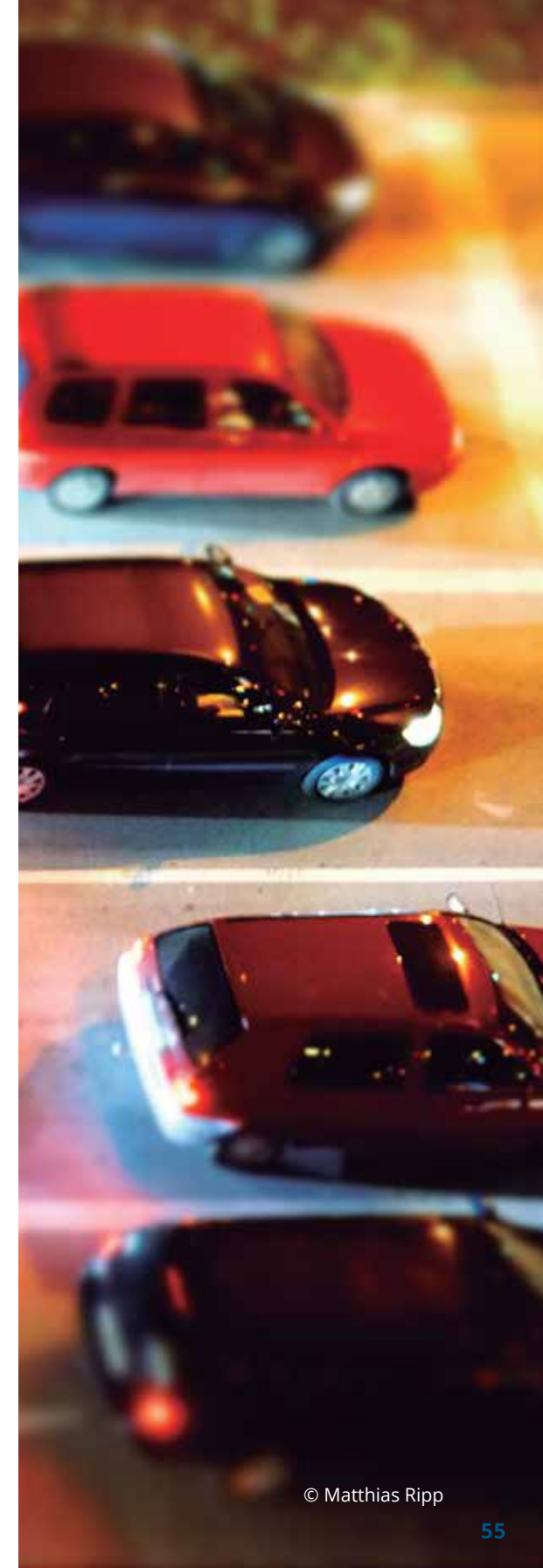
models to choose from when purchasing a new vehicle. Similarly, because the overall market is small, manufacturers do not always offer as many different vehicle configurations or options, such as additional equipment, styling options or multiple battery/motor options. The cost of a car for a consumer could potentially be reduced if one could choose, for example, the battery capacity most suitable for each individual's driving patterns. Moreover, many electric vehicle models often come with state-of-the-art technical extras and with no option to remove them to reduce the purchase price.

Matching electric vehicles with driver needs

Drivers have become accustomed to how conventional vehicles will cope with distance, their handling and performance, and other factors such as fuel supply, the different manufacturers and associated branding, and engine sound.

Switching to electric vehicles challenges drivers, as they are very different from conventional vehicles in many of these respects. Electric batteries, unlike petrol or diesel, force manufacturers to decide between maximising loading volume and minimising vehicle weight on the one hand and maximising driving range on the other.

Potential users consider that two main reasons they would not buy an electric vehicle are that they are not as suitable for everyday requirements, particularly in terms of range and charging limitations, and there is less choice of models. Although the battery



range of most electric vehicles currently on the market is sufficient for the vast majority of journeys that consumers undertake, users say that their minimum required range is larger. Similarly, slow overnight AC charging is actually sufficient to meet most consumer needs, but it takes a longer time than users say is the maximum acceptable (Vogt and Bongard, 2015).

Some users of electric vehicles install charging points within the private grounds of their home or company. Nevertheless, nearly all users rely on public charging networks as a fall-back solution. Even though the numbers of public charging points are increasing, in most parts of Europe they are still considered insufficient and viewed as a major obstacle to using electric vehicles.

Limited information

Many potential users do not know or understand the capabilities of modern electric vehicles. This can often be a bigger barrier than concern about the use of new technology (NRC, 2013 and 2015). This is especially true of charging infrastructure. Potential users criticise the poor quality of the information available about charging points, access and payment methods. As a result, non-users expect more problems in the everyday use of electric vehicles than experienced users actually encounter (Vogt and Bongard, 2015).

In addition, car labelling provides information on fuel consumption and CO₂ emissions, with the aim of enabling consumers to make an informed decision about purchasing a new car. However, most

car-labelling schemes in EU Member States do not provide information that is tailored to battery electric or plug-in hybrid vehicles. For example, they do not give information on the electric driving range.

Technological uncertainty

Electric vehicle technology is more than 150 years old. In the early 20th century many manufacturers made battery-powered cars; their lack of vibration, smell and noise were seen as clear advantages over the early petrol- and later diesel-fuelled vehicles. However, they cost more than internal combustion engine vehicles and could not go as far. This led to a decline in their use, especially after the discovery of large petroleum reserves in the early decades of the 20th century made affordable fossil fuels widely available.

Consumers today consider electric vehicle technology a relatively recent development. Therefore, they think that some aspects are uncertain, such as vehicle range, charging availability and costs of ownership. They are particularly concerned about battery life expectancy. However, for a normally used car that most of the time was slow charged, it is considered extremely unlikely that the battery will fade below 80 % capacity before 250 000 km. The potential users believe instead that if the battery does not last as long as expected, either the resale value will fall or the owner will have to buy an expensive new battery. In contrast, conventional vehicles have been optimised over many decades, and users feel they are able to assess the potential risks of ownership (van Essen et al., 2015; NRC, 2013 and 2015).

Survey of electric vehicle owners: perceptions versus reality?

A survey of 1 721 electric vehicle owners in Norway shows that they experience few disadvantages, that the number of households with only electric vehicles is growing and that almost all of the owners plan to continue buying electric vehicles.

In Norway, electric vehicles are commonly used for daily travel, especially to work, and the average electric vehicle drives about the same number of kilometres annually as an average conventional vehicle. Most owners do not change their travel patterns and most electric vehicles are bought to replace a conventional car. When they acquire an electric vehicle as an additional vehicle, some respondents drive more — a potential drawback in terms of environmental impacts. Electric vehicle owners tend to have high incomes and live in large households in or around cities, like other multi-car owners. They value the economic and environmental benefits of electric motoring, and electric vehicles meet their transport needs. Media and social networks seem to be the most important channels for spreading knowledge about electric vehicles within Norway.

A parallel survey of 2 241 conventional car owners reveals a growing interest in electric motoring; one third of this group were actively considering buying an electric vehicle next. If current incentives in Norway continue, the market share of electric vehicles will probably continue to increase.

Source: TØI, 2014.

Measures that promote electric vehicle use

A number of measures are available to encourage consumers to use electric vehicles. Such incentives are designed and implemented at different governance levels, from EU legislation that provides a framework promoting low-emission vehicles, through national measures such as introducing lower taxes for electric vehicles, to local incentives such as free inner-city parking and use of road lanes normally reserved for public transport.

EU initiatives to promote electric vehicles

European-level legislation is used to encourage the development of low-CO₂ technologies in transport, such as electric vehicles and advanced biofuels.

Two EU regulations set mandatory targets for average CO₂ emissions for new passenger vehicles (EU, 2009a) and vans (EU, 2011). These regulations establish effective CO₂ emission targets for each manufacturer, depending on vehicle weights and types. The targets for new passenger vehicles and vans were both met several years before the deadlines (2015 and 2017 respectively). However, there is a growing discrepancy between the official test measurements and real-world emission measurements (EEA, 2016c). This means that in recent years actual on-road vehicles have reduced their emissions more slowly.

From 2021 onwards, the average target for the entire new car passenger fleet will be 95 g CO₂/km. It takes only exhaust emissions into account in this context, so it treats BEVs as zero emitters. As an incentive to

manufacturers, so called 'super credits' were introduced for vehicles with emissions lower than 50 g CO₂/km, giving such vehicles extra weighting when calculating average emissions. Electric vehicles, as well as low-emitting hybrids, are therefore helping manufacturers achieve their targets.

The 2021 target of 95 g CO₂/km is not viewed as sufficient in itself to help electric vehicles penetrate the market at a high rate, but rather designed to help improve vehicle efficiency in general.

Other examples of EU legislation include the Fuel Quality Directive (EU, 2009b) and the Renewable Energy Directive (EU, 2009c), which require respectively a reduction of the GHG intensity of fuels used in vehicles and a 10 % share of renewables in the transport sector by 2020. Both directives focus on the deployment of biofuels, but they can support electric vehicles indirectly, as Member States can credit energy use by electric vehicles toward their targets.

The Alternative Fuels Infrastructure Directive (EU, 2014) requires Member States to set targets for recharging points accessible to



the public, to be built by 2020, to ensure that electric vehicles can circulate at least in urban and suburban areas. Targets should ideally include a minimum of one recharging point per 10 electric vehicles.

The recently published European strategy for low-emission mobility highlights the need of moving towards low and zero-emission vehicles and scaling up the use of renewable electricity for transport and removing obstacles to the electrification of transport. It stresses the need for further rollout of recharging infrastructure, interoperability and EU-wide standardisation for electro-mobility. The objective is to allow a car journey across Europe, making electric vehicle charging as easy as filling the tank (EC, 2016).

National actions to support electric vehicle use

A combination of supporting incentives and coordinated policy is key in accelerating electric vehicle market development. There are many examples of ways in which national governments provide subsidies to consumers who purchase or use new electric vehicles. These include purchase tax exemptions, one-off grants or increasing taxes on fossil fuel use (which makes electricity a more attractive fuel). The level at which incentives are implemented and the amount of subsidy paid may differ greatly between countries.

One-off purchasing subsidies

Certain countries have used various types of one-off subsidies to encourage the purchase of electric vehicles. Reducing registration tax or exempting new vehicles is common. Reductions can range from 100 % of the normal registration

tax, i.e. full exemption (in Belgium/Flanders, Greece, Hungary, Latvia, the Netherlands and Portugal among others), to a more limited reduction (e.g. Denmark, Finland). Some countries reduce the tax by a defined amount (e.g. Ireland).

Reducing registration tax is not the only way in which tax elements have been used to reduce the financial cost for customers who wish to purchase electric vehicles. Norway has for example exempted electric vehicles from value added tax (VAT). Several countries, including Norway and Iceland exempt electric vehicles from import tax (Aasness and Odeck, 2015).

A number of governments co-fund purchases. Such schemes generally consist of grants or premiums given by national governments to those customers who purchase electric vehicles. The method used to define the amount of the grant or premium differs between countries. Some countries, such as Sweden and Romania, apply co-funding to all purchases of cars with low CO₂ emissions. In France, Germany, Spain or the United Kingdom, the subsidies depend on the technology and category of vehicle.

A number of Member States also offer additional means of financial support. In France and Portugal, a fixed grant is available for replacing an end-of-life vehicle with a new electric car.

In Belgium, the government of Flanders gives grants only to individuals purchasing electric vehicles; leasing and company cars are not eligible (Vlaanderen, 2016). However, in some countries tax reductions apply to companies as well (e.g. France, the Netherlands, Portugal and Sweden).

Reduced ownership costs

Drivers in many countries must pay an annual circulation tax that is required to drive a vehicle on a public road. Yearly tax exemptions or reductions usually focus on this cost element. Exemptions to circulation tax differ between countries, including by:

- the amount and/or the percentage of circulation tax reduction/exemption;
- the type and size of the electric vehicle;
- ownership (private individual or company);
- the period of the exemption or reduction.

Some examples of time limits are found in Germany, Italy and Sweden. Circulation tax exemptions for electric vehicles in Italy and Sweden apply only during the first 5 years of ownership and 10 years in Germany.

Belgium, Cyprus, Greece, Hungary, the Netherlands, Portugal, Slovakia, Sweden or United Kingdom have also introduced exemptions from the annual circulation tax. In Latvia, owners of electric vehicles are exempt from car and motorcycle tax and also from vehicle operation tax. The Austrian government exempts electric vehicle owners from monthly vehicle taxes.

Belgium and Portugal also offer the opportunity to deduct tax from corporate income if companies use low-emission cars. Portugal created incentives for battery electric and plug-in hybrid vehicles by increasing the maximum amount of depreciation acceptable as tax expenses and reducing separate tax rates on individuals' and companies' income taxes. Ownership benefits in Denmark to support fuel-efficient

cars include for electric vehicles, tax reduction and for hydrogen fuel cell vehicles full exemption (annual as well as purchase).

Some Member States have introduced incentives for the purchase of electric vehicles by reducing energy and/or electricity costs. At least six EU Member States (the Czech Republic, Finland, France, Germany, Poland and Spain) provide discounts for charging electric vehicles based on peak and off-peak prices. Such demand-responsive charging, or 'smart charging', provides an opportunity to reward consumers financially if they reduce their electricity usage or shift it to cheaper off-peak periods.

Financial support to the electric vehicle industry

Many countries support research and development to encourage technological innovation for low-emission vehicles. One example can be found in Finland, where the government launched a 5-year Electric Vehicle Systems Programme (EVE) in 2011 with a total budget of around EUR 100 million. Its main aim was to create the financial conditions necessary to support and grow the electric mobility technology and service sector. From the beginning the focus was on encouraging companies to develop international business opportunities. Pilot, test and demonstration projects were seen as important, as well as collaboration with partners from different areas of the electric vehicles industry.

A number of governments, as well as regional or local authorities, have financially supported the installation of electric vehicle charging infrastructure. As one example, since 2012 the French Environment & Energy Management Agency (ADEME) has allocated funds to a charging infrastructure support fund. It does this through its Future Investment Programme (PIA). In 2015 this fund supported the installation of more than 5 000 charging points in France. Many other governments promote deployment of charging infrastructure for electric vehicles. These include Belgium, Croatia, Denmark, Estonia, Germany, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. However, the investment funds and the targets differ significantly among countries.

In Sweden, individuals who would like to install a charging point for an electrical vehicle in their homes may get a tax reduction for the associated labour cost.

Local government actions to support electric vehicle use

Local authorities across Europe have implemented a range of different measures designed to encourage uptake of electric vehicles. Often developed in conjunction with national authorities, to ensure that the appropriate legal basis for their implementation is in place, local measures are often (but not necessary) non-financial. Examples of such measures include:

Public procurement of electric vehicles. Municipal authorities use vehicles for

many purposes including public transport, transport for the elderly and service cars for municipal workers. Local authorities are increasingly ensuring that electric vehicles are part of their public procurement contracts. One third of local councils in the United Kingdom, for example, now operate at least one electric vehicle (Intelligent Car Leasing, 2016). In the Czech Republic, municipalities, regions and local government agencies receive about 20–30 % subsidy when purchasing a car with alternative technology. Public procurement and use of electric vehicles can be important factors in increasing public awareness of electric vehicles as a potential option within urban areas, and of course it can reduce the environmental footprint of authorities.

Provision of free parking places for electric vehicles. As part of its National Action Plan for the promotion and uptake of green vehicles for 2012–2014, Bulgaria gave electric vehicles free parking throughout all of its cities (Macdonald, 2014). The German government similarly gives municipalities the option of offering various benefits to electric vehicle drivers, including free parking (Tost, 2014). From July 2016, electric vehicles can park free of charge in Latvia. Free public parking has been introduced in Cyprus as well.

In Amsterdam, inhabitants with an electric car have priority over other inhabitants when applying for a parking permit.

Provision of free charging at public stations. Certain countries, including Bulgaria, the Czech Republic and Denmark, have introduced free charging at public

stations. The scheme is being piloted in Portugal.

Use of lanes reserved for public transport, such as bus lanes. Some countries, such as Estonia, Germany, Latvia, Norway and the United Kingdom, permit municipalities to open individual bus lanes to labelled electric vehicles.

Access to restricted areas or city centres for low-polluting vehicles. In Italy and Greece, electric vehicles are given access to restricted areas, such as city centres. In Germany, the Electric Mobility Act has also exempted electric vehicles from certain restrictions.

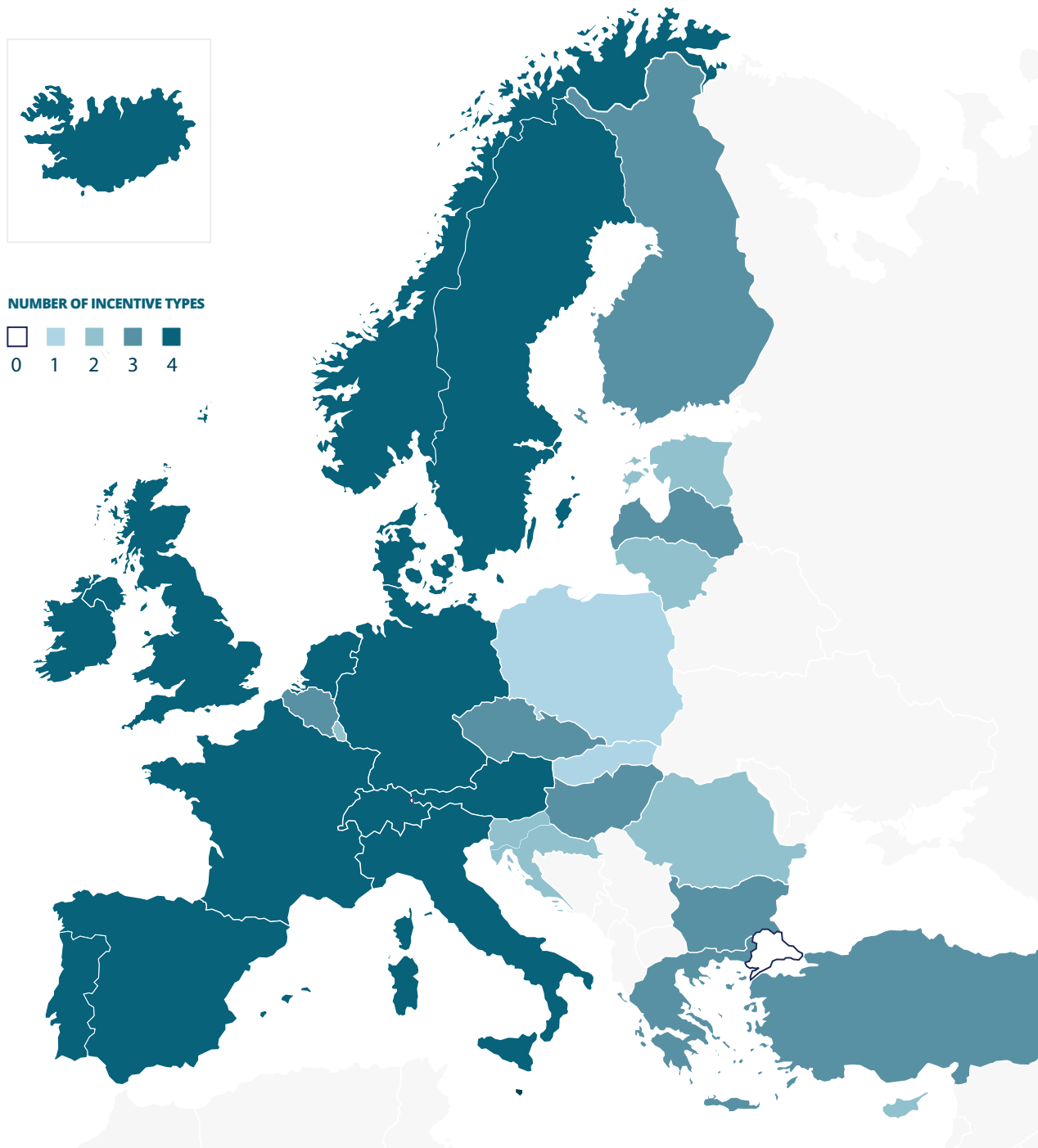
Road toll exemptions or discounts. In Norway, battery and fuel cell electric vehicles are exempted from road tolls. These vehicles are also exempted from fees on national ferries (Hannisdahl et al., 2013). The regional government of Catalonia in Spain has newly developed car labelling and exempts electric vehicles from road tolls. It has developed a zero category for electric vehicles, REEVs and PHEVs with electric ranges of more than 40 km.

Supporting measures to educate and promote electric vehicle use. The Belgian Platform on Electric Vehicles (BPEV) was launched in 2010. The goal is to promote and disseminate information about electric vehicles. The platform includes all of the principal stakeholders involved in the field of electric transport in Belgium (Belgian Platform on Electric Vehicles, 2011). The Netherlands support the use of electric vehicles with consultancy, education and

promotion (Nederland elektrisch, 2016). The Hague has for example introduced subsidies for new and second-hand completely electric cars (EUR 5 000 and EUR 3 000 respectively) for its inhabitants. Amsterdam also subsidises the purchase of electric vehicles (cars, vans, taxis, trucks) if they are to be often used in Amsterdam.

Grouping of authorities. In January 2016, four cities in the United Kingdom (Nottingham, Bristol, Milton Keynes and London) were awarded significant funds (GBP 40 million in total) to promote green vehicle technology. These cities will deliver an increase in cutting-edge technology, such as fast-charging hubs and street lights that double as charge points, along with a range of innovative proposals that will give electric car (battery and plug-in hybrid) owners extra local privileges such as access to bus lanes in city centres. They will also open up around 25 000 parking spaces for electric car owners, saving commuters as much as GBP 1 300 a year (Go Ultra Low City Scheme, 2016).

Use of incentives for electric cars across Europe



	PURCHASE SUBSIDIES (purchase-related tax exemptions or reductions, registration tax, import tax, co-funding or other financial purchase support)	OWNERSHIP BENEFITS (annual tax exemption, reduction of electricity or energy costs)	BUSINESS AND INFRASTRUCTURE SUPPORT (business development or infrastructure support)	LOCAL INCENTIVES (free parking, access to bus lanes, no toll fees, free charging, access to restricted areas in city centres)
AUSTRIA	✓	✓	✓	✓
BELGIUM	✓	✓	✓	
BULGARIA	✓	✓		✓
CROATIA	✓		✓	
CYPRUS		✓		✓
CZECH REPUBLIC	✓	✓	✓	
DENMARK	✓	✓	✓	✓
ESTONIA			✓	✓
FINLAND	✓	✓	✓	
FRANCE	✓	✓	✓	✓
GREECE	✓	✓		✓
GERMANY	✓	✓	✓	✓
HUNGARY	✓	✓		✓
ICELAND	✓	✓	✓	✓
IRELAND	✓	✓	✓	✓
ITALY	✓	✓	✓	✓
LATVIA	✓	✓		✓
LIECHTENSTEIN				
LITHUANIA	✓			✓
LUXEMBOURG	✓		✓	
MALTA	✓	✓	✓	✓
NETHERLANDS	✓	✓	✓	✓
NORWAY	✓	✓	✓	✓
POLAND		✓		
PORTUGAL	✓	✓	✓	✓
ROMANIA	✓	✓		
SLOVAKIA		✓		
SLOVENIA	✓			✓
SPAIN	✓	✓	✓	✓
SWEDEN	✓	✓	✓	✓
SWITZERLAND	✓	✓	✓	✓
TURKEY	✓	✓	✓	
UNITED KINGDOM	✓	✓	✓	✓

Note: The level at which incentives are implemented and the amount of subsidy paid may differ greatly between countries.

Source: EAFO, 2016; EEA, 2016d; EEA Eionet consultation.



Looking forward to a more sustainable transport system

Making internal combustion engines more efficient will not be sufficient by itself to achieve the EU's ambitious goals for reducing carbon emissions and developing a more sustainable circular economy. A shift towards more non-motorised and/or public transport will be a key factor in making the transport sector more sustainable, as will changing behaviours about the demand for mobility. However, in the short and medium timescales, people will continue to use motorised road vehicles, and therefore developing new, cleaner technologies such as electric vehicles is necessary.

Recent years have seen an increasing public and media focus on climate change and air pollution. Emissions from road vehicles play a substantial part in both these issues. Consumers are understandably interested in being better informed about the impacts of different vehicles on climate change and air quality.

Developing alternative-fuel vehicles will help reduce the burden that the transport system places on the environment. However, it will not solve other problems such as congestion, road safety and land use challenges. Fundamental changes in the transport system, including technological solutions and behavioural change, are therefore needed to reduce its harmful impacts. Encouragingly, there is some evidence of a cultural shift away from car use in certain regions, particularly among the younger generations. At the same time, cycling, using a car pool and opting for public transport are becoming more popular (EEA, 2015b).

European policy is supporting the transition to a more sustainable circular economy and decarbonised transport system. The main elements include: encouraging resource efficiency, ensuring high quality recycling and developing markets for secondary raw materials, encouraging eco-innovation, breaking the oil dependency, optimising and improving efficiency of transport system, moving towards low and zero-emission vehicles, supporting development of new sustainable fuels, and scaling up the use of low-emission alternative energy for transport such as renewable electricity and removing obstacles to the electrification of transport.

For the research and policy communities, it is clear that initiatives that drive vehicle technology improvements and fleet renewal can be one of the main strategies for reducing emissions of both GHGs and air pollutants, significantly improving local air quality in cities. Despite the significant technological progress made over recent decades towards cleaner engines, traffic emissions account for a high proportion of Europe's air and GHG pollution.

Conventionally fuelled vehicles can still improve their performance. However, in moving towards Europe's longer-term objective of achieving a low-carbon society, it is becoming clear that incremental improvements in vehicle efficiencies will not deliver the substantial GHG emission reductions and improved air quality needed in the future.

In the research area, incentives that support the development of advanced low-carbon technologies will continue to be needed, for example research into improved batteries, and new hybrid, electric and fuel cell technologies. Measures that encourage the continual development and uptake of clean technologies in the transport sector will be fundamental for the future reduction of transport's impacts on health and the environment.



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Further information

AVERE, the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles www.averre.org	Information on electric vehicles, including links to national associations.
ChargeMap Chargemap.com	ChargeMap is a community-based service aiming to list all the public or semi-public charging points for electric vehicles.
Clean fleets www.clean-fleets.eu	Project supporting public authorities in implementing clean vehicle procurement.
European Alternative Fuels Observatory www.eafo.eu	Information on the development and deployment of alternative fuel vehicles, infrastructure and incentives.

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For your notes

Electric vehicles in Europe

Transport underpins our society. It connects people, cities, countries and economies, fostering growth and employment. However, transport also damages the climate, the environment and human health. To reduce these impacts, Europe needs to move towards a more sustainable circular economy and decarbonised transport system.

Electric vehicles are one of the ways in which Europe can move towards a more sustainable transport system. This report provides a non-technical summary of the latest information on electric road vehicles in Europe, including those with hybrid technologies.

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