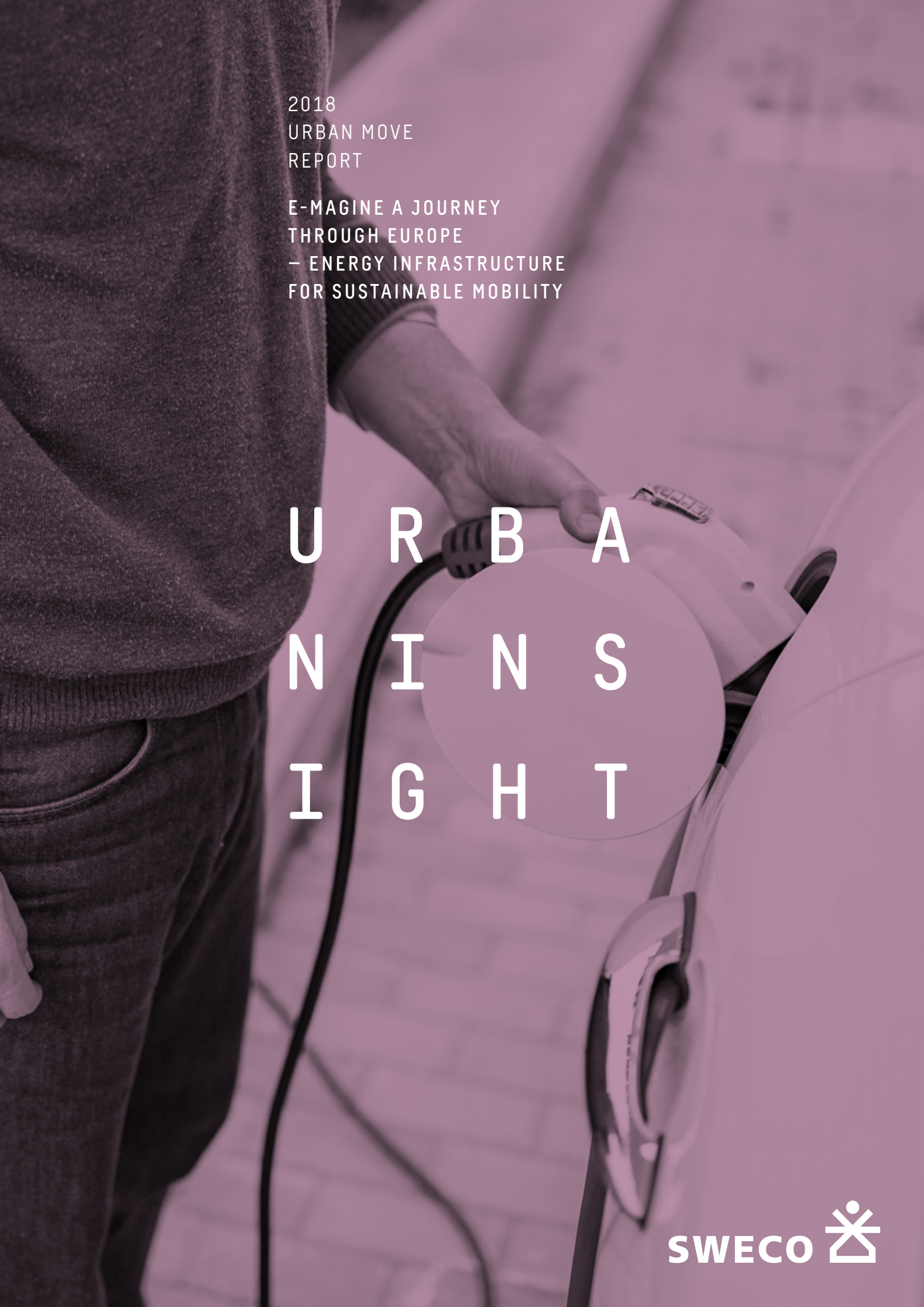


2018
URBAN MOVE
REPORT

# E-MAGINE A JOURNEY THROUGH EUROPE – ENERGY INFRASTRUCTURE FOR SUSTAINABLE MOBILITY

# URBAN INSIGHT

SWECO

# E-MAGINE A JOURNEY THROUGH EUROPE – ENERGY INFRASTRUCTURE FOR SUSTAINABLE MOBILITY

TIM VAN DEN MAAGDENBERG

# IS IT FEASIBLE TO TAKE A ROAD TRIP ACROSS EUROPE IN AN ELECTRIC CAR TODAY?

**CONTENTS**

# 1. INTRODUCTION

Reducing emissions associated with mobility is one of the core challenges that needs to be addressed on the road to achieving a sustainable society. Countries across Europe are exploring different alternatives to fossil fuels. In light of this development, electro-mobility has risen high on the agenda of politicians and city planners. How far has Europe come when it comes to e-mobility? And how does infrastructure differ between countries? In this report the authors set out on an imagined journey across Europe in an electric vehicle (EV) to provide insight into the state of existing sustainable mobility infrastructure.

For some decades now, there has been awareness of the need to plan and develop sustainable mobility for the future. A sustainable energy technology is defined not only by its environmental impact, but also by its future availability, economic feasibility, and (perhaps most importantly in the case of sustainable mobility) its compatibility with societal developments such as urbanisation and globalisation.

This report focuses on electric vehicles and their integration into society in coming years, and analyses the state of alternative fuel vehicles and facilities across Europe today. The report presents a case study that was conducted to examine the feasibility of travelling long distances today in an electric vehicle, in the form of an imagined journey across Europe based on data from several different journeys. Finally, the report looks into the future and considers the demand and requirements for modern energy infrastructure that can meet expectations and technical demands for the development of sustainable mobility.

Modern daily transport is heavily reliant on fossil fuels and, as a result, there is a need for drastic changes in the sector. Efforts are underway on the European and national level – as well as in individual cities and municipalities – to improve efficiency and energy supply availability, and to adapt and mitigate the effects of climate change. Some major European cities are developing their own programmes to achieve cleaner mobility in

the future. Special focus has been placed on electro-mobility (e-mobility), particularly from the European Commission. Due to the concepts already developed in the automotive industry and the existing potential for increased uptake of electric vehicles, this technology is particularly well suited to being promoted across the continent, accelerating development in the industry.

Other sustainable fuels are being developed in parallel with EVs. Measures to develop infrastructure for hydrogen vehicles are being implemented in for example the UK, Norway, the Netherlands, Germany and Finland.

Figure 1. Countries supporting the development of electricity as an alternative fuel.

# 2. ALTERNATIVE FUELS AND TECHNOLOGIES OF INTEREST

This section defines the characteristics of the three main sustainable "alternative fuel technologies": electricity-, hydrogen- and biofuel-powered vehicles, and describes the different types of chargers available for electric vehicles (the most common type of alternative-fuelled transport).

## VEHICLES

### ELECTRIC VEHICLES

Electric vehicle technology is available in various forms. Firstly, the Battery Electric Vehicle (BEV) is powered solely by an electric motor using electricity that is stored in an on-board battery. This battery must be regularly charged with electricity from the grid or, for EV owners, with on-site renewables (e.g. from solar PV), and will allow an electric driving range of 80 – 400 km (European Environment Agency, 2016), depending on battery type and capacity.

Hybrid Electric Vehicles (HEVs) combine a conventional combustion engine with an electric motor system. The HEV battery utilised in this type of vehicle is rather small and cannot be charged from the grid. Instead, the battery is charged from regenerative braking, in which an energy recovery mechanism converts kinetic energy into a form that can be used immediately or stored until needed. Due to battery size, HEVs have a limited electric driving range of up to 50 km.

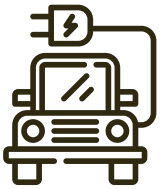
Plug-in Hybrid Electric Vehicles (PHEVs), on the other hand, use the electric motor as a main engine, with the combustion engine used only when the battery is low or when higher operating power is required. As the name indicates, the larger battery can be charged from the electricity grid to obtain an electric driving range of 20 – 85 km. The third hybrid type, the Range-Extended Electric Vehicle (REEV) is powered solely by an electric motor supplied with electricity from the battery. This battery is charged from the grid, but also from a small combustion engine acting as a generator, which only activates when the vehicle exceeds its battery-only driving range. This allows an EV driving range of 70 – 145 km (European Environment Agency, 2016).

### HYDROGEN VEHICLES

Fuel Cell Electric Vehicles (FCEVs) are also fully powered by an electric motor. However, compressed hydrogen gas is used as fuel to generate the electric power via a fuel cell. The fuel cell is an electro-chemical cell that converts the chemical energy from the reaction of hydrogen and oxygen into electricity. Depending of the size of the fuel tank, FCEVs currently have a driving range of 300 – 700 km.

### BIOFUEL VEHICLES

First-generation biofuels such as biodiesel and biogas are derived from food crops and have come under fire for threatening biodiversity and contribution to deforestation. Second-generation biofuels, also known as "advanced biofuels", are derived from feed stock, waste and recycled vegetable oil and do not cause the same level of harm to the environment (Hockenos, 2017). The driving range is the same as for conventional fossil fuels.



### ELECTRIC ROADS

Another interesting technology for heavy vehicles, as well as for cars, is electric roads – a vehicle receives electrical power from power lines running above the road or placed within the body of the road. The world's first electric road opened in Sweden in 2016 and is a two-kilometre strip where electrified lorries use conductive technology developed. The system permits lorries to operate as electric vehicles when on the electrified road and as regular hybrid vehicles at other times (Scania, 2016).

## EV CHARGING OPTIONS

Hydrogen and biofuel-powered vehicles can be refuelled in a similar timescale as petrol or diesel vehicles. However, EVs currently take from between 30 minutes to 12 hours to charge, depending on the charger and the battery capacity. Battery and charging technology is advancing rapidly, so it is expected that within a decade it will be possible to recharge a large-battery EV within 10 minutes.

### RAPID CHARGERS (PRIVATE ONLY)

Rapid chargers are high-power AC or DC chargers outputting 43 kW AC, and 50 kW or 120 kW DC directly into the EV battery. They utilise a tethered cable, specially designed for safely delivering the power to the vehicle and to provide two-way communication between the charger and vehicle. Chargers usually have three types of cable and connector to allow the various car makes to charge according to their rapid charging socket. This type of charger is primarily used when on longer journeys, where rapid charging is a necessity. Due to the cost of installing this type of charger and the amount of power it can deliver in a short time, it is often common to pay a premium price to charge, sometimes on par with petrol price equivalent. Rapid charging parking spaces must only be used during charging, e.g. 30 minutes to 1 hour.


### FAST CHARGING STATIONS (PUBLIC, WORKPLACE AND DOMESTIC)

Fast charging stations allow EV drivers to connect 7 - 22 kW power to the EV's on-board charger. These stations are sometimes used for destination charging, allowing drivers to stay for as long as they need to utilise the parking space. The EV must be moved when the time expires. Some of these charging points have signs specifying a parking/charging time limit, e.g. 4 hours. Drivers therefore cannot rely on there being a space for charging, even in instances where a car occupying a charging space has finished charging. In these cases, green/red signs (see page 13) would be useful, as queuing drivers would be able to see when the occupier of the space might be returning, or could contact them to find out their expected return time.

### SLOW CHARGING STATIONS (PUBLIC, WORKPLACE AND DOMESTIC)

Slow charging points allow EV drivers to connect to a socket or dedicated station that delivers up to 3 kW (10 A). These are usually classed as destination charging stations, mainly because they take up to 12 hours to charge. As with public fast charging stations, drivers searching for a public slow charging station should not rely on there being a space for charging, even if the car occupying the space has finished charging. This type of station is usually also without a tethered cable and plug, so drivers use a special cable to connect. UK 3-pin or EU Schuko sockets can also be used for slow charging, but require a special adaptor and controller (EVSE) to safely connect to the car.

# 3. "E-MAGINE" – A CASE STUDY JOURNEY THROUGH EUROPE

E-magine is a case study that illustrates the development of e-mobility infrastructure in different parts of Europe. The journey is fictional, but the data and descriptions have been compiled from several actual European journeys and studies.

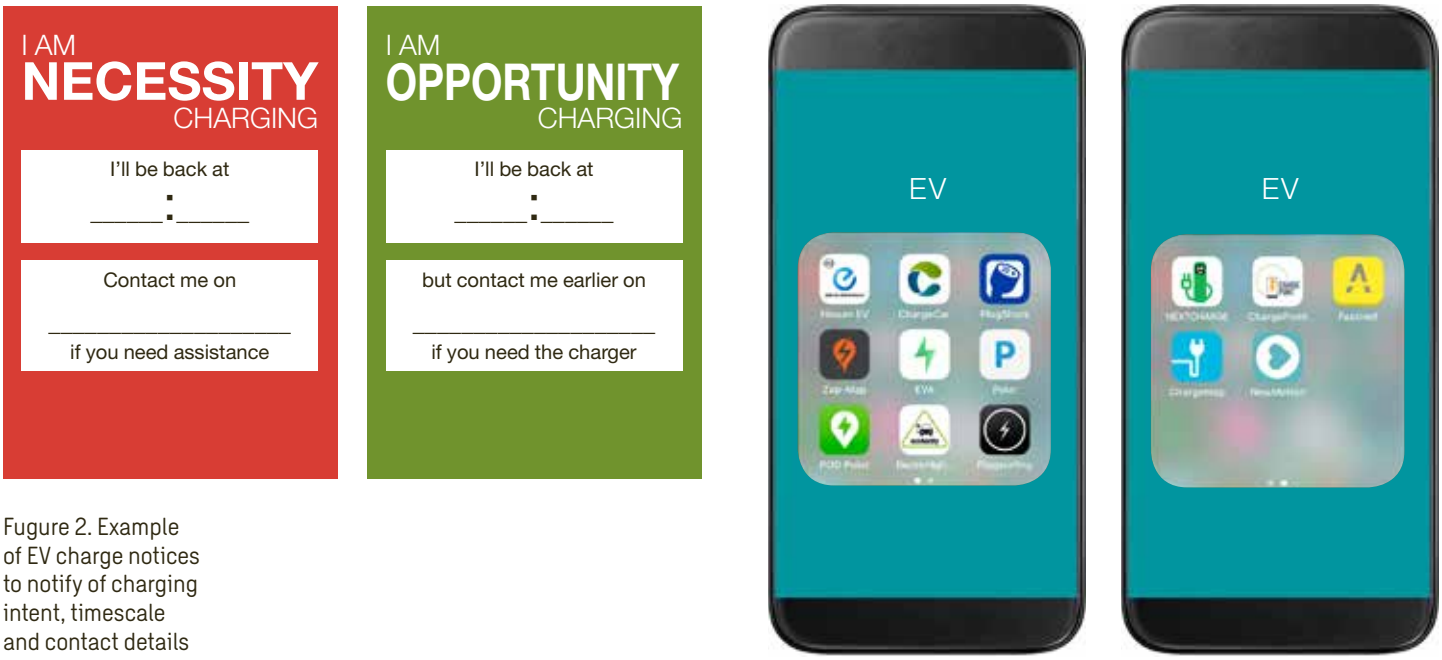
> "In early spring, we decided to take a family road trip through Europe, starting from our home town near London (UK). Our children (Rachel, 11, and Joe, 9) were not very enthusiastic at first, but when we promised to visit Legoland they were eventually convinced. We had recently purchased a new car with a full electric driving range of 200 km (124 miles). So, we had the whole package: an adventure, a new car, two enthusiastic kids and the chance to visit some destinations we had always wanted to see."

The family on a road trip through Europe.

We used the weeks before our trip to adapt to our new car and the changes to our familiar driving habits. We had bought a car with rapid charging capacity. Unfortunately, we found that, despite clear signage, many of the public charging bays with rapid charge sockets in our hometown are blocked by slow charging cars. Some PHEVs come with a rapid charge plug, but due to limited rapid charge infrastructure, they can only charge slowly or accept a small charge. We immediately recognised the major challenge at charging bays of being accidentally or deliberately, "ICEd" – blocked by a standard Internal Combustion Engine (ICE) vehicle – either intentionally (because charging spaces are usually close to the main entrances of supermarkets etc.) or due to poor signage/ignorance, or plain malice. We support a system where charging intention/ requirement notifies other chargers of timescale and usage. An example of how this could be implemented is to inform other drivers about your intention by placing signs on the windscreen of your car (see Figure 2).

As it turned out, we needed to do an inordinate amount of research and planning to prepare for our road trip with an EV. We needed to download far too many mobile phone applications to locate all necessary charging stations for our journey (see Figure 2). Ordering the various charging cards was also a hassle – more on this later.

> "Fasten your seatbelt! Let's start our trip in the UK, with the capital as our first destination."




Fugure 2. Example of EV charge notices to notify of charging intent, timescale and contact details and example of mobile applications required for various charging stations.

We needed to charge our battery for the first time in London. Next to our charging bay, a worker at a nearby construction site was about to pull cables from a shaft near the kerb. He informed us that the City of London nowadays requires that all new developments include a certain percentage of charging points or the infrastructure ready to install charging points. "What a good idea for future development!," we thought. The construction worker reported that the additional charging points being provided exceed demand in the city. While rapid charging, our kids used the time to play games on their tablet.

We used the spare time to research more about the current general sustainable mobility situation in the UK. Clearly, many councils have been introducing more and more charging points lately, with some cities (e.g. London, Milton Keynes and Dundee) installing more than others. However, it does seem like the charging network needs further development to make it much more widespread and reliable. It would certainly be helpful to have more rapid chargers (>43kW), and it is a positive sign that mainstream petrol stations are rolling out rapid chargers across the UK. Before we bought the new car we researched expected future EV charging costs, and it appeared that these may be on par with petrol prices in the coming years for rapid charging.

In terms of public transport, we also discovered that less than half of the British rail network is electrified as of July 2017. Roughly 95 kilometres of existing track has been electrified since 1997 – 50 of these since 2010. The government's plans to electrify the country's railways, announced in 2009, have in many cases not been implemented, with plans being scrapped or suffering severe delays (Rai17). The UK has more electric buses than any other country in Europe (a few hundred) – but this pales in comparison with China (close to 200,000) (Transport Network, 2017).


Figure 3. A public rapid charging bay before getting on the Dover-Calais ferry.

> "We finally leave London and drive to Dover, to hop on the ferry to Calais. Armed with so many phone applications for on-route charging stations, we feel well prepared for our European EV adventure. But we find the array of different charging plugs and sockets at the stations confusing. Thankfully the phone applications allow you to filter according to your preferred charging type. Although the overall charging station infrastructure is good, we are unable to use every charging station we come to. It looks like we have to gamble a bit."

The charging infrastructure near Calais looked poor when we checked the app, so we had to top-up our car at a service station before the ferry. This would allow us to drive far enough into Belgium to reach a suitable charger. Hopefully in the near future, it will be possible to charge your car while on a ferry, but there are obvious carbon emission implications for doing this until ferries use greener fuels.

Once in France, we headed through Belgium to Cologne, Germany.

For such a big city, Cologne has fewer charging stations than we expected – or rather, they are not as easy to spot as conventional petrol stations. Once we located a charging point, we met a Tesla driver waiting for his car to finish charging. He told us that he loves his "toy", but that he has needed to change his habits quite a lot. He has a private charging station on his property and his company, like some other German companies, is changing its fleet to electric vehicles and providing charging stations. He mentioned that it must be even harder to have an electric car without a private charging station, or supported stations in nearby locations such as workplaces. The search for a free parking space in major cities is terrible as it is. On top of this, it is virtually impossible to find a charging station with the right plug. We asked him why Germany is so behind the times when it comes to this technology. He said that the former German government, back in 2012, announced a target of having one million electric cars by 2020 (Bundesregierung, 2012) – but in 2017, the chancellor revoked this target without setting a new policy (Mortsiefer, 2017). Since then, e-mobility in Germany has not been a top priority on the German political agenda.

In Cologne, we also discovered that use of free chargers often requires some form of ID, such as a non-payment membership card, to prevent the (sometimes malicious) premature termination of a charging session – usually to allow the offender to jump the charging queue. This also locks the charging cable into the charger (both slow and fast chargers) to reduce risk of cable theft or premature unplugging.

While charging at a rapid station, our kids used the time to play on their tablet.

One evening we parked our car at a rapid charger, to prepare for the next day. Apparently, chargers' emergency stop buttons are frequently misused to terminate charging sessions by people who want to jump the charging queue! We were lucky this time, but it would have been extremely annoying to have come back to find that our battery hadn't been charged as much as we were expecting.

> "On our way to Norway we visit Legoland in Denmark, as we promised Rachel and Joe. We are getting used to the disadvantages of driving BEVs. The promised rapid charger turns out to be just a domestic-type plug."

The traffic increased on our way to Oslo and we were passed by several EVs driving in the bus lane. We played it safe and stayed in the main lane, but took the opportunity to ask another EV driver about this at our next charging stop. The proud owner of a 1999 Th!nk explained to us that there are a lot of benefits for EV buyers and owners in Norway. Owners get free municipal parking, access to bus lanes and free travel on toll roads and ferries. EVs are also exempt from purchase tax and VAT, but as the share of EVs increases (29 per cent market share in 2016), some of these benefits are now under revision. The Norwegian parliament has set a target of zero or low emissions for all new cars (PHEV, BEV, FCEV) by 2025. The City of Oslo imposed a two-day ban on diesel vehicles in early 2017 due to high amounts of NOx caused by unfavourable weather conditions, with warm sea-borne air covering the city and keeping emissions at low altitude.

As we rolled up the charging cable, the Th!nk owner told us about the new car he recently ordered – a Fuel Cell Electric Vehicle. There are already a few hydrogen refuelling stations in the Olso area, with more on the way.

> "On our way to Stockholm, Sweden, we are reminded of another disadvantage with EVs: if you're travelling through Europe and using public charging stations, even within a single country, you need several different mobile phone apps and membership cards. Some chargers rely on apps, others on cards – while others allow you to use a combination of these, or a website. Only a few can accept credit/debit cards! It can be very confusing and complicated – even more so if the driver is in a country where they don't know enough of the language to navigate the chargers or websites. At worst, you can find yourself stranded with an empty battery and need to be towed to a nearby charger. So a lot of preparation is needed before you start your trip – you may need to order a card to be delivered to your home address."

Figure 4. Public charging bays in Sweden.

Our trip had already taught us that, even within a single country, there are various charging operators that have their own, often unique ways of accepting payment for charging or for starting and stopping a charging session. A borderless, membership-free and app-free charging network or payment method would be ideal. It would make things much easier if there were credit/debit card payment options and radio frequency identification (RFID) options available at all charging stations that require payment or ID verification. Next generation chargers in some countries are moving towards this payment method, particularly for rapid charging stations.

However, the drive over to Stockholm was uneventful. With some planning, we found charging opportunities at fast food restaurants, shopping malls, hotels, etc. We never ran into the problem of fully occupied charging stations. On the other hand, we weren't travelling during peak holiday season.

At one petrol station, Joe (who was by then also interested in sustainable mobility) noticed that several different fuel options are provided, in addition to petrol and diesel – such as E85, bio-diesel (FAME, HVO[1]) and biogas. The station owner explained that there is a law specifying that all petrol stations must provide at least one renewable fuel option. In addition, large amounts (up to 50 per cent) of biofuels have been created by blending it with petrol and diesel. Sweden has a long tradition of biofuel production, although electrification is currently the strongest trend. Several public transport bodies are piloting electric buses and planning large-scale vehicle roll-outs in coming years.

In Stockholm, we were easily able to find a slow charging spot for overnight charging. These are available in most public parking garages in the city centre. While visiting some museums, we discovered that all public transport in Stockholm is fossil free.

1) FAME: Fatty Acid Methyl Esters, HVO: Hydrotreated Vegetable Oil

> "After a very cold night, Rachel is especially happy about one particular EV feature – the ability to switch on the car heating remotely from my phone, so she can hop into a warm car on a frosty morning. We're relieved that we don't need to scrape a thick layer of ice from the windscreen, like other drivers! We leave our hotel and drive south, staying in Copenhagen and Berlin on our way to Warsaw. Once in Poland we leave the motorway twice to charge in city centres. Between Poznań and Łódź, we need to charge up a bit at a regular petrol station using an electric socket and extension cable. Currently, if you live in Poland, EVs are only suitable for city driving due to the limited charging infrastructure."

In Warsaw we stopped at a commercial centre, where the only free parking place was close to the entrance and marked in green – a space for EVs! Lucky us! In that huge car park crowded with ICE vehicles, it seemed like there were no EVs. A quick internet search taught us more about the current mobility situation in Poland. In 2016, more than half of newly registered cars were used cars (Statista, 2018). Since most second-hand cars are imported (mainly from Germany), the share of electric vehicles is low.

Entering the shopping mall, we came across an exhibition of modern small car designs. Speaking with the company employee, we learned that Polish power companies were running a contest for electric car designs with the aim of creating an affordable electric car using Polish design and technology. We got the feeling that there will be some major changes in future.

She apologised for cutting short our conversation, saying that it was the end of her working day and that she needed to hurry and reserve an electric scooter to get home. She told us that she can do this using a mobile app, and that there are many electric scooters available in the city for by-the-minute rental. She claimed that this is the best way to get around in the city centre during rush hour.

Figure 5. Reserving an electric scooter using a mobile app.


Figure 6. Road map showing charging stations used.

> "We are now halfway through our European road trip and are heading back home. We've charged our car 25 times so far, spent a total of 12 hours at charging stations and spent 2 hours charging from an electric socket. If we were to do this trip again, we would plan activities to do during the stops wherever possible, as we were not fully prepared for waiting around."

The family road trip showed us that e-mobility infrastructure varies substantially, even between neighbouring countries. There are many promising initiatives underway, but there is still a lot that can be done to make electric vehicles a practical choice for long trips between different European countries.

Figure 6 shows our journey route and the charging stations we used along the way.

# 4.
# CONCLUSIONS AND RECOMMENDATIONS


CHARGING
START/STOP

It is clear that alternative fuels will become further integrated into society in coming years. Currently, it appears that EVs will dominate passenger transport, although hydrogen vehicles are also developing quickly and may become a significant market player. There will most certainly be a variety of alternative fuel resources available to power our future transport sector – although there are also many challenges to deal with.

## PROMOTING ELECTRIC VEHICLES TO THE PUBLIC

In addition to making technological advancements in vehicles and infrastructure, we need to make the industry more visible and drive change through marketing. One idea would be to more widely promote new technologies and make the EV driving experience available through an easy-to-use rental service. Electric buses that offer smooth transport through the city and by-the-minute electric car and scooter rentals within city centres would provide hands-on user experience and help allay any fears or concerns potential buyers may have.

## POLITICAL INITIATIVES

Political and strategic levers are in place on various levels to drive the development of e-mobility, but more initiatives are needed to enhance this development. EVs combine many infrastructure market characteristics in terms of economies of scale, network effects, high investment costs and low marginal costs. Third-party costs from the current petrol-dominated vehicle fleet, including climate influences and health effects, also make a good case for political intervention.

Oslo and many other major Scandinavian cities offer free access to bus and taxi lanes for electric vehicles. Countries like Poland and Germany offer subsidies and tax incentives for EV buyers. Some countries are planning to ban sales of new fossil fuel-powered vehicles (including vans). In the UK, the initiative is part of a £3 billion strategy that will urge local governments to retrofit buses, alter roads and even tweak traffic-light patterns in order to reduce emissions and improve efficiency (Boulter, 2017). This ban is scheduled to take effect in 2040 in the UK, while the Netherlands aims to achieve this goal by 2030 (Pieters, 2017).

## HIGHER AVAILABILITY OF CHARGING POINTS

The recharging of vehicles powered by alternative fuels is one of the main bottlenecks slowing down the expansion and distribution of these technologies. Charging can take up to 8 hours at a standard charging station (CEP, 2017). Figure 7 provides an overview of the range achievable with alternative fuel supplies based on travelling distances to and from Cologne, one of the stops in the case study described in the previous chapter.

Figure 7. Overview of potential fuel range to and from Cologne.


We need to find ways to minimise fuel range anxiety and concerns about congested charging points for people travelling on specific pre-planned routes. One good example of this is found in Sweden, where most EVs sold are Plug-in Hybrid Electric Vehicles (PHEVs) and therefore able to complete most journeys without needing to be charged. However, there are still many Battery Electric Vehicles (BEVs) on the roads that need to be charged much more frequently and urgently. We therefore need to ensure that some form of priority charging system is put in place as we move forward.

Improved infrastructure in urban areas is one prerequisite for success. The approach taken in London appears promising: new developments should ensure that a certain percentage of parking spaces are equipped with charging stations. Although there is still a long way to go, we should eventually be able to match the number of EVs with a suitable number of EV charging points. Motorway rapid charging takes this a step further. Expanding the network across countries is a major challenge in fully integrating EVs into our societies.

## QUALITY OF CHARGING POINTS

The focus is often on quantity when talking about charger availability, probably because it is easy to monitor and communicate. But this issue should not be solely about numbers or power loads – focus should rather be on balancing the right amount of chargers with the appropriate power requirements. Some chargers installed at new developments (e.g. new sports facilities or office buildings) might be used only rarely. The reason for this mismatch is the lack of charging infrastructure in the current climate, and this calls for further assessment and a deeper understanding of the needs that are most important to EV owners and potential future buyers.

A country's various regions have different requirements, and this also calls for further analysis. Rural and suburban areas, for example, often offer better options for home charging than city centres, where most cars are parked on the street with no access to home charging. It might therefore be more effective to provide chargers at workplaces rather than trying to place chargers in an already over-crowded environment. The competition for land in city centres indicates that the space should be used for purposes other than charging cars. Furthermore, the cost of grid power connection for superchargers is much higher in city centres, which makes it desirable to evaluate other locational options. Rapid chargers are more essential along transport routes with large volumes of through traffic.

The future may see an electric car with a short-range battery charging from contactless inductive chargers around cities and a long-range hydrogen tank enabling long journeys and trips on minor roads that do not provide charging facilities. The objective is to make the most of what we are able to do now and prepare to do even more in future.



## CAREFUL UTILISATION OF EXISTING NETWORKS

Even the most sensational EV is not a desirable option if it regularly blows a house fuse or causes a substation power failure when charging at the same time as the neighbour's EV. Our existing infrastructure is a result of years of investment, improvement and redevelopment. Careful utilisation of our existing networks is of paramount importance while adapting to new sustainable technologies. Load management will be critical in managing peaks in power demand. In areas with high concentrations of EVs we can expect demand peaks of entirely new dimensions, as people come home from work and charge their vehicles while also cooking and using other electrical appliances.

Other interesting advances in technology include vehicle-to-grid (V2G), where plugged-in EVs can be used to provide local power network balancing and EV owners rewarded for providing this service. Careful automated control of V2G will ensure that EV owners are not inconvenienced by having their batteries discharged excessively.

## HARMONISATION OF PLUGS AND CHARGERS

As highlighted in the E-magine case study, a vast array of plugs and chargers are currently available in the market. Combined with major differences in charging station quality, it is essential to ensure that responsibility is assigned in terms of driving change in this area. It could be argued that European countries need to come together and specify a mandatory, integrated approach to e-mobility, enabling the EV industry to work to specific standards and bring all infrastructure in line with a common standard. This uniformity would also reduce costs and promote a common market for alternative fuels.

Charging station payment methods also need to be coordinated. Hurdles will remain high until EV motorists know they can pay safely and securely. Navigating among dozens of applications, cards and accounts is also frustrating. Paying for electricity needs to be as simple and uncomplicated as paying for petrol, and vehicles need to be able to cross borders without having to use multiple pieces of equipment.

# 5.
# ABOUT THE AUTHOR

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The theme for 2018 is Urban Move, describing various facets of sustainable mobility and accessibility.

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