Data visualization of the current state of electric mobility infrastructure

Creative Technology

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Abstract

The goal of this graduation project is the visualization of the current state of Emobility infrastructure. Having a reliable and convenient charging infrastructure in place is the key factor to achieve widespread adoption of Emobility. The target audience includes companies related to the field, such as OEMs, charging network providers, as well as people who have a general interest in understanding the challenges facing the industry.

To accomplish this, research in the field has been deducted and the key factors which are defining and influencing the state of infrastructure have been outlined. Existing visualizations related to the Emobility infrastructure as well as similar domains have been analysed. A total of five visualizations have been designed to represent the current state of electric mobility infrastructure. Those include the distribution of charge points among the world, charging networks within Europe, charging speed, range of EVs (Electric Vehicles) and the relation between purchase price and range of EVs. The results have then been tested and re-evaluated with people representing the two target groups. They have then been implemented and presented on a landing page together with the findings of Gleb Podorozhnyy, whose project focused on the market side. Presented as a story and including background information as well as interesting facts and figures, an extensive overview of the current state of Emobility has been created. Hubject hopes to benefit from the project by attracting new clients as a thought leader of Emobility.

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1 Introduction

To tackle the problem of climate change, the target of achieving zero-emission urban freight transport by 2030 as well as zero-emission urban passenger transport by 2050 has been set by the European Commission [22]. To achieve these goals, a shift in the transport sector from vehicles dependent on fossil fuels to alternative, less fuel-dependent transport systems is necessary [17]. However, not all of the countries are as ready with their infrastructure as their laws showcase them to be. While the introduction of electric vehicles is key for the shift to electric mobility [18], also the growth and expansion of the charging networks, technical capabilities, and other supporting technologies in the field of electric mobility are important factors.

E-mobility and charging networks can be a complex topic that varies from country to country and while the government, technology and infrastructure developments clearly contribute to Emobility, consumer concerns about electric vehicles appear to be a sticking point for large-scale introduction [50].

1.1 Objectives & Challenges

The goal of the graduation project is designing understandable and informative visualizations to raise awareness of the current state of e-mobility. The focus will be on the infrastructure side, as this is the key factor which will facilitate confidence in using electric vehicles in Europe while insufficient infrastructures will slow down its adoption. Consequently, this is also boosting demand for electric vehicles as consumers are also growing confidence to take long-distance travel in their EVs [4] [6].

1.1.1 Target Audience

The target audience consists of companies related to the field of E-mobility, such as OEMs, charging network providers etc., as well as people who have a general interest in understanding the challenges facing the industry.

1.1.2 Expectations & Goals

The goal of this graduation project is to provide the audience with reliable information using visualizations and additional facts & figures and to educate people about the current state of Emobility infrastructure. The main requirements from the client side were the following:

- The design should be visually appealing as well as match the visual identity of Hubject

- The visualizations must be both educational and marketable
- The project should be presented in such a way that it can be combined with the Project of Gleb Podorozhnyy (Data visualization of the current state of Emobility market)

Fulfilling the above-mentioned requirements should contribute to strengthen the image of Hubject as a thought leader of Emobility. This should ultimately lead to attracting new clients for Hubject.

1.1.3 Measurements

In order to measure the success of the landing page, several parameters will be set by Hubject's marketing team. Among others, those include the number of website visitors compared to the number of reaches, the number of leads to the primary Hubject website from the landing page, time spent on the page, and lastly the number of shares of the visualizations.

1.1.4 Challenges

The main challenge of this project is creating new, innovative and truthful visualisations for each part of the Emobility infrastructure that provides interesting insights both for regular website visitors as well as for experts in the field.

A second challenge will be connecting those visualisations through one coherent storyline which, as a whole, strengthens the picture of Hubject as a thought leader in Emobility. This project will be combined with the project of Gleb Podorozhnyy, whose focus is on the market side. Together, a comprehensive overview of the current state of Emobility should be provided.

Another major challenge will be creating the user interaction and to develop the website responsive on all devices. Designing with mobile and tablet interfaces in mind will mean a smaller screen space to display the visualisation and has to be kept in mind when designing such.

1.2 Research Question

The main research question for this thesis can be formulated as follows:

How can the current state of Emobility infrastructure be visualized in a user engaging format?
In order to answer the above question, the following sub-questions have to be answered:

1. What are the characteristics that define the infrastructure of Emobiliy?
2. What are the challenges of the Emobility infrastructure?
3. What are political motivators that affect the Emobility infrastructure?
4. How is the charging infrastructure distributed around the world and within Europe?

5. What type of data visualizations are currently available in regard to Emobility?
6. What are interesting insights of Emobility infrastructure that not have been visualised yet?
7. How can visualizations be designed in such a way that they are both interesting for the general public as well as experts of the field?

2 Theory and Background

For the successful completion of the project, the understanding of theory and background of Emobility is necessary. Therefore, a literature review on the infrastructure of Emobility in Europe has been conducted. In addition, already existing visualizations of the field as well as other related topics have been analysed and evaluated.

2.1 Literature Review on the infrastructure of Emobility in Europe

Several research projects [19,20,21] have addressed the problem that the infrastructure for electromobility is still in its early stages and point to many obstacles and challenges for the successful diffusion of electric vehicles across Europe. Despite the great interest in this area of research, there is a lack of studies that provide an overview. Acceptance of EMobility is still low compared to vehicles with conventional fuel and the mobility concerns from a consumer perspective are still high [16].

In the following research, the state of the infrastructure in Europe will be analysed to gain background information of the context. The present study intends to answer the question; what is the status of the infrastructure of Emobility in Europe? Using literature resources, it will explore the Emobility infrastructure by (1) examining the electric vehicle (EV) charging ecosystem as well as (2) identifying barriers and (3) political motivators that affect Emobility.

2.1.1 What Does the Electric Vehicle Charging Ecosystem Look Like?

2.1.1.1 What different types of charging stations are available?

The current charging network consists of various types of standardized chargers. They are standardized so that the public charging points are shareable by most EV users. The types of chargers available in the market are AC fast, DC fast, and superchargers. Charging stations are classified according to speeds of charging or type of ownerships namely private and public ownership. In terms of charging speed characteristics, there are level 1 chargers (household 120 volts), level 2 chargers (240 volts), level 3 and level 4(fast charging types) [8]. Since Emobility is still at infancy, the majority of early adopter’s charge cars at home or at the workplace [7]. For the people who do not have access to charging infrastructure at home or work because they live in apartments, public charging greatly determines electric car usage. The demand for public charging infrastructure increased by up to 60% between 2013 and 2018 [7] and as at the end of 2018, there were already 600,000 public electric car charging points globally.

2.1.1.2 What charging specifications are being used for chargers?

The charging ecosystem is gradually transforming as new standards are being proposed for manufacturers. An example is the IEC 62196-2 EV plug standard by the International World Electric Vehicle Journal 2018 which sets three types of alternative current (AC) charging plugs as the common standards for EV manufacturers [9]. These prototype plugs are type 1 developed by SAE international, type 2 manufactured by Mennekes, and type three initially made by EV Plug Alliance [9]. Major global car manufacturers like Porsche, ABB and Energon have embraced these Emobility charger specifications by installing 350kW ultra-fast charging prototype stations in attempts to facilitate compliance [10, 11, 12]. Innovations in charging are also underway and the future promises cable-less charging systems that are placed on the road and charging occurs while the electric vehicles are in motion [15].

2.1.1.3 How did the charging network develop in Europe?

At present, the number of EV charging stations is sufficient because the number of electric cars being used is low. For example, in central Europe, the number of fast-charging stations required to suffice the demand for charging stations is 314 only [6]. This target was already hit in 2018 [6] but because the number of electric vehicles is expected to rise sharply over the next few years [8], increasing demand for more charging stations is imminent. In the large EU region, the ratio of electric vehicles to charging stations currently stands at 7 cars to one charging station while the estimated number of charging stations is 185,000 [6]. In terms of preference, slow AC charging stations make up 61% of the total public charging station usage although infrastructure for fast and ultra-fast charging points, estimated to be 9000 CCS and ultra-fast 640 respectively [6], is also rising across Europe.

2.1.1.4 How well are the Charging Stations connected?

The urban corridor between Southern UK and the Netherlands covering German Rhineland, southern Germany, and Switzerland has the highest number of fast chargers having an estimated ratio of 5-7 electric vehicles per charging station. The Netherlands stands out as a pioneer of Emobility especially because it provided the blueprint for Emobility infrastructure for other nations through its charging infrastructure assessment platform that offered real-life charging data. The country currently has the highest number of charging stations and subsequently the lowest ratio of EVs to charging stations of 4 cars to 1 charger. The EU recommends that the number of charging infrastructure should be 1/7th to 1/10th of the total number of electric vehicles. States that still haven't achieved the EU recommendation of 1 charging station to 10 EVs infrastructure include Cyprus, Sweden, Finland and Greece which all have a ratio of more than10 EVs to 1 charger [4]. Belgium, UK, and Ireland's infrastructure ratio is 10 EVs to 1 charging point and have therefore met the recommendations. The EU plans to have 1.3 million public charging stations by the year 2025 and 3 million by 2030 [6].

2.1.1.5 How are the charging facilities distributed in Europe?

To be able to cover all passenger car flows within Europe, the EV charging stations are placed strategically [8]. The frequency of charging infrastructure distribution in EU motorways stands at one fast-charging station per 60 kilometres. However, this distribution tends to be highly concentrated in urban areas of countries like the Netherlands, Germany, France and the UK [4]. In the deployment of charging stations, strategic placement of the infrastructure is critical as highlighted in studies of Jochem et al [3] which predicts that Germany will have the highest number of stations, not because it has huge market demand for EV cars but because of the diverse and high-density road network.

On the other hand, France is expected to have a higher number of charging stations in 2030 as well because of a high EV market share and the subsequent workload expected [3]. Disparities in EV distribution among EU countries are also visible for example as of 2017 the registered number of EV's in the Netherlands was 119,000 and the country had 32,000 charging stations while Greece had an estimated 300 EVs and 40 recharging stations only [4]. Globally, other leaders in Emobility besides the Netherlands are the US, China, and Norway [4].

2.1.1.6 How does the expansion of the charging network affect the shift to Emobility?

Consumer behaviour and attitude towards e-mobility is greatly influenced by the availability of EV charging infrastructure [13]. A highly developed charging infrastructure network will facilitate confidence in using electric vehicles in Europe while insufficient infrastructures will slow down its adoption. The positive news is that the charging network is developing in Europe and globally as well. The stakeholders including car manufacturers, property owners and governments, are playing a vital part in this feat by putting charging facilities at accessible areas such as parking lots and supermarkets [7]. Consequently, this is also boosting demand for electric vehicles and the carmakers are responding adequately. Owing to the improved network of charging points, drivers are also growing more confident to take long-distance travel in their EVs [4] [6].

2.1.2 What are the Barriers to Emobility?

2.1.2.1 Grid overload

One problem that faces the e-mobility revolution is that integrating the charging infrastructure in the electricity distribution grids poses a significant challenge. The demand and cost of electricity could surge rapidly if appropriate measures are not taken to address the anticipated increase in power consumption by the EVs [1]. Scholars predict that by the year 2030 fifteen percent of cars in the EU roads will be electric and as a result, an estimated 3% of the electricity consumption will be by electric cars [4]. When many cars charge at the same time and from the same grid, it is likely that voltage overloads and band violations may become prevalent [5,] [8].

Such problems can be avoided by encouraging EV owners to charge at pre-established convenient times when the electricity grid is not overwhelmed, and electricity is less costly [1] [4] [8]. In fact, by promoting such smart charging methods the expenses required to upgrade the EU electricity grid systems can be lowered and consumers would still have positive attitudes about purchasing or using EVs [1]. Research needs to be facilitated to find intelligent car charging and discharging solutions so that the grid burden is minimized in the future when EV car numbers increase [24].

2.1.2.2 Charging and power storage challenges

E-mobility is also plagued by challenges of power storage including battery capacity, price, and charging durations [2] [8]. Hogging, which implies leaving the charging plug for long after the car is fully charged, is still a major challenge as statistics indicate that only 20-40% of the charging connection time in the EU stations [2] and 15-25% in the Netherlands facilities [25] is used for useful charge. However, the hogging problem is not as severe as portrayed because only 1% of charge sessions usually take more than 48 hours [2]. Also, estimations point out that there is always an alternative charging point in 50% of sessions where the charging lasts more than 24 hours [2]. Since the number of EVs is expected to increase in the EU as well as demand for charging, hogging has to be addressed through policing so that facilities are used responsibly.

2.1.2.3 The high cost of electric vehicles

A third challenge facing Emobility is that the price of electric vehicles tends to be higher than those of conventional cars [23]. Although this impedes EV acquisition, EV enthusiasts suggest that consumers can be sensitized about the benefits of having such cars such as low maintenance costs and the compensatory incentives they get for low pollution [4] [23]. Additionally, e-mobility faces the problem of parking pressure at the charging spots and this will heighten as more electric cars are purchased.

2.1.3 What are the motivators of Emobility

2.1.3.1 The influence of politics on the Emobility market

Politics play a significant role in driving e-mobility especially by influencing the number of EV sales. For example, the New European Driving Cycle (NEDC) [27] testing regulation has spurred Emobility industry via a purchase tax scheme that penalizes vehicles emitting high CO2 and rewards the low emitters. Through this system, vehicles whose emissions are near zero are excluded from paying the annual vehicle tax and as a result, this incentive offers the EV users an opportunity to save as much as €1500 per year on vehicle-related expenses [7]. Additionally, businesses using EVs for transportation in the Netherlands, and Germany [4] as well get tax reductions on the annual depreciation as an incentive for using low-emission mobility.

The EU often enacts policies to level the playground for EV manufacturers and promote e-mobility in the region. Among the interventions which have been made to facilitate Emobility are; Europe on the Move legislations of 2017 [4]; the Connecting Europe Facility grant for developing charging infrastructure [4]; and the €200 million investments on battery research promised between 2018 and 2020[4]. Another key legislation is the 2020/2021 CO2 guideline which demands that by 2020 an average of 5% of the sale-share by car makers should be from EVs or they risk fines [6]. This standard will not only ensure more electric cars are produced and sold in the EU but also lower the prices. By projections, there we could witness more than 200 EV car models sold in Europe by end of 2021[6] and by 2025 the region could attain a 4 million per year EV production [6].

2.1.3.2 The influence of politics on the distribution network

Besides influencing EV sales, politics also have an impact on the distribution of charging stations [7] [13]. For example, one reason why the Netherlands had the densest charging facility in the world by 2018 was because of the financial support given by its government to grid operators in 2009 to establish a network of 10,000 charging points [26]. The EU as a whole is also, through policing, influencing how charging stations are spread within its members. The commission's Energy Performance of Buildings Directive, for instance, specifies how new and upcoming non-residential buildings should have at least one EV charging point. It also directs that older non-residential buildings undergoing renovations should meet this specification if they have more than

10 parking spots [4] [6]. Furthermore, one out of five parking spaces of these non-residential buildings is required to have conduits that allow for the charging point to be set up [6].

Part of the reason why the EU is fastening the Emobility progress is that it wants to reduce CO2 emissions from the transport sector [5] [9]. Its goal is to eliminate greenhouse gases from freight transport in cities and reduce gasoline fuelled cars by 50% in 2030 and then remove such automobiles from urban roads by the year 2050 [5]. The EU wants to achieve a distribution rate of at least 1 re-charging facility to 10 electric [5] [6] cars in all member states and policing is one approach it is using to meet this target.

2.1.4 Conclusion

E-mobility, still at its infant stages, is expected to grow and become the dominant means of transportation across Europe and the world. This is mainly motivated by sustainability goals such as cutting down on greenhouse gases that negatively affect global climate. One challenge that stakeholders of Emobility should address adequately is the availability of charging infrastructure. This has been pointed out in various studies used in this paper and has been directly linked to the progress of Emobility. That is, the more available and accessible the Emobility infrastructure, the higher the confidence of consumers to use or purchase electric vehicles.

Most notable from the referenced studies also is that the EU block plays a key role in spurring Emobility especially because it provides financial support, guidelines, and policies on how member states should approach Emobility. Netherlands stands out as a dominant player in this industry and seems to offer the blueprint for other nations that want to integrate Emobility successfully. A major challenge for the EU in implementing Emobility is that interstate policies, protocols, and infrastructure are not harmonized. For this reason, mobility of EVs across borders is still restricted by the conflicting interoperability standards.

It should be pointed out that a majority of literature resources used in this study were deficient in addressing the high costs of EVs as a problem and how this is impacting the Emobility agenda. However, this did not impact the quality of evidence presented regarding the current position of Emobility especially with regards charging infrastructure and policies. Future studies that may want to replicate this approach should include the high cost of EV as another important challenge impeding growth of the industry.

2.2 Existing data visualization approaches

To create data visualizations that are meaningful and add value to the viewer, it is important to first research which data has already been visualized and what tools have been used to do so.

As research papers usually only contain limited and basic data visualizations, it has been decided to also include other, non-scientific sources such as news journals, web platforms and websites. Also, the scope of the research was extended and visualizations of related topics such as climate change or mobility in general, have been included as well for the purpose of inspiration.

2.2.1 E-Mobility

2.2.1.1The number of electric cars worldwide

The number of electric cars available on the market as well as the total number registered is one of the main indicators that show the rapid development of Emobility within the last years. At the beginning of 2019, the number of plug-in electric vehicles increased globally to 5.6 million including cars and light commercial vehicles with battery-electric drive, range extenders, and plug-in hybrids [28]. The European leader is still Norway [29], whereas globally China is first and the U.S second [30]. While there are a lot of visualizations regarding this topic available, the type of visualization used to showcase the rapid development is almost always a simple line or bar chart (an example can be seen in Figure 1).

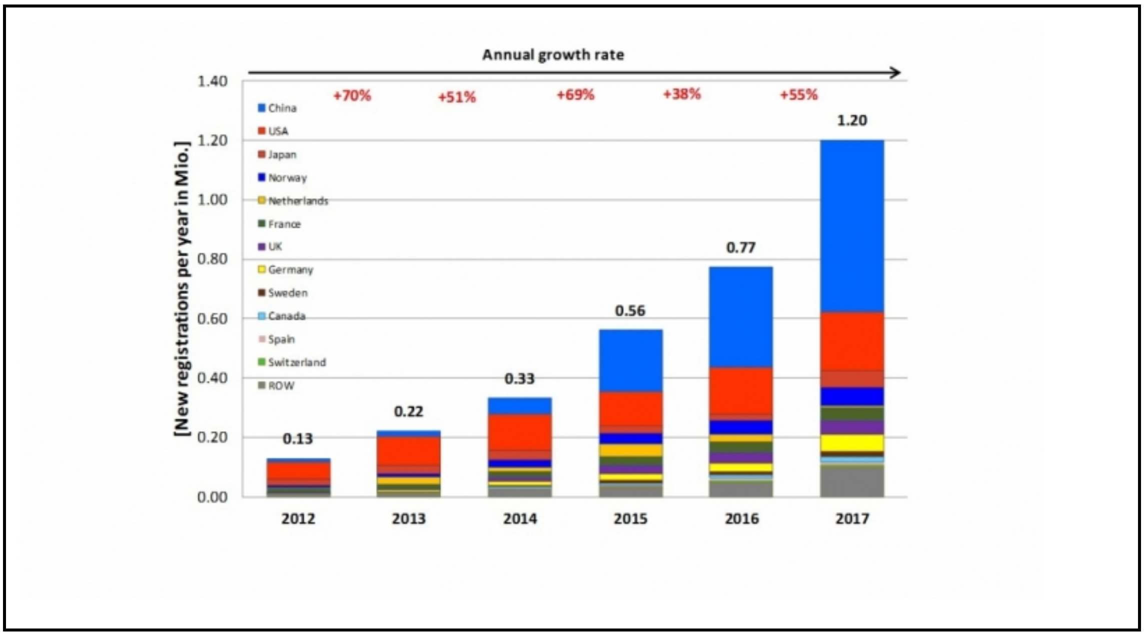


Figure 1 New registrations per year in Mio. [29]

Regarding the three different types of electric drive vehicles available on the market, a more interesting visualization could be found as can be seen in Figure two. Here, the share of each type of the category is compared as well as the share of them in regard to the total vehicle sales in the US.

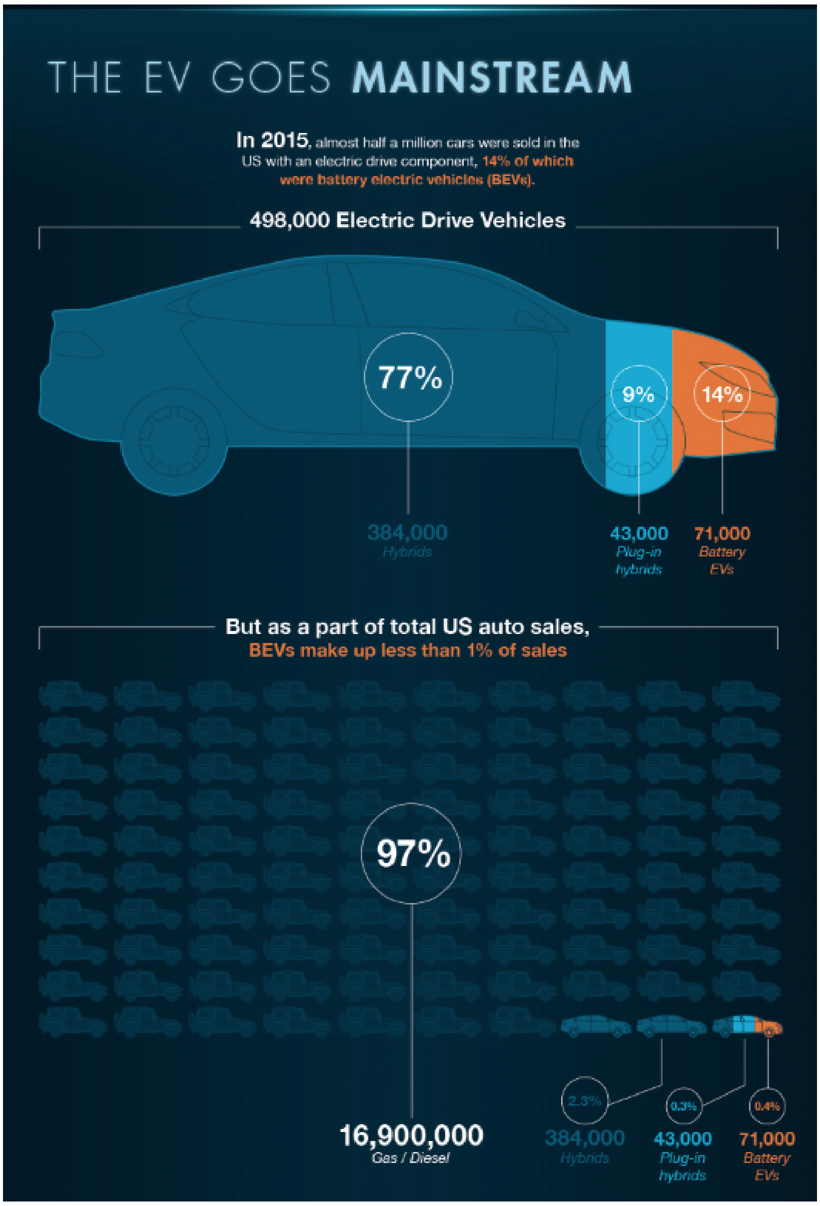


Figure 2 Visualization of the share of each electric vehicle type within all Evs as well as the percentage of BEVs in regard to the total market [31]

The latter is an interesting fact which sets the total number of EVs in the context of the switch from fossil fuel cars to electric vehicles. Even though the growth rate of EV sales compared to the previous years is high (Figure 1), Norway is the only country in Europe where people almost prefer purchasing electric vehicles (Figure 3).

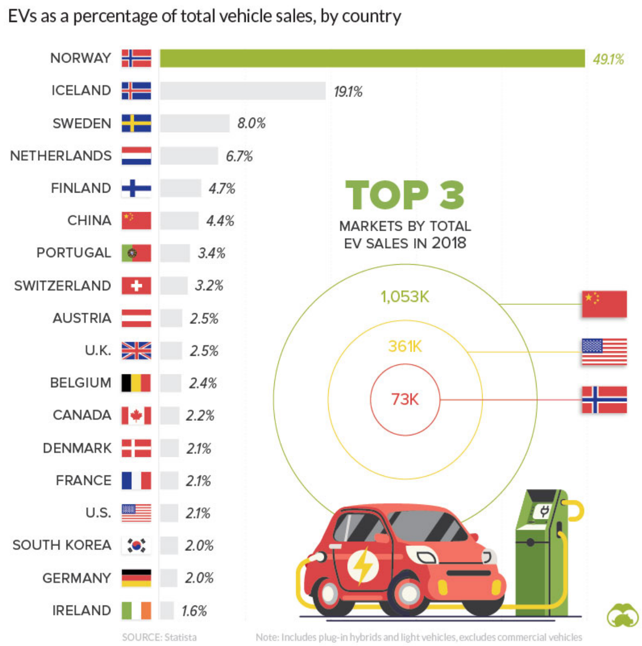


Figure 3 EVs as a percentage of total vehicle sales by country/ Markets by total EV sales in 2018 [18]

To make EVs more attractive to consumers, automakers have to come up with new models in all price ranges. With the number of models growing from less than a hundred in 2019 to more than 300 within the next four years (Figure 4), sales are expected to increase. Especially because Volkswagen announced that its first EV will be cheaper than gasoline cars [32].

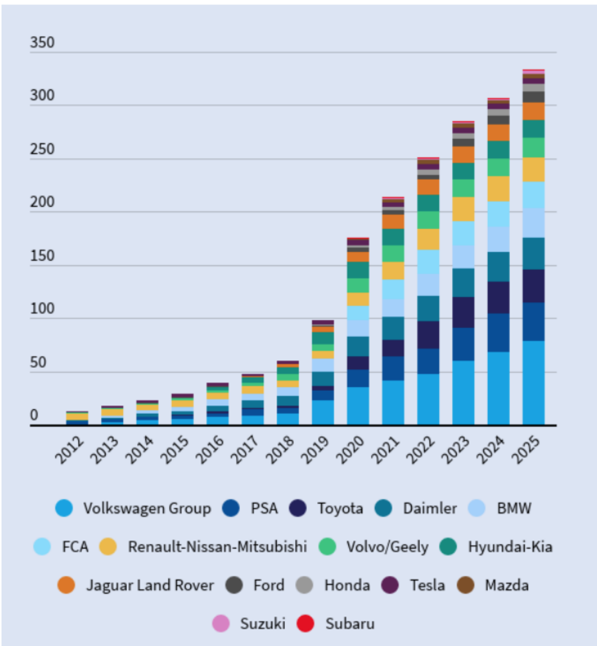


Figure 4 Number of EVs available on the European Market [33]

2.2.1.2 The charging network

A high number of electric vehicles will inevitably lead to high electricity demand as well. In Total, an extra of 1.900 TWh will be required. To store this power, many extra batteries will be needed (Figure 5).

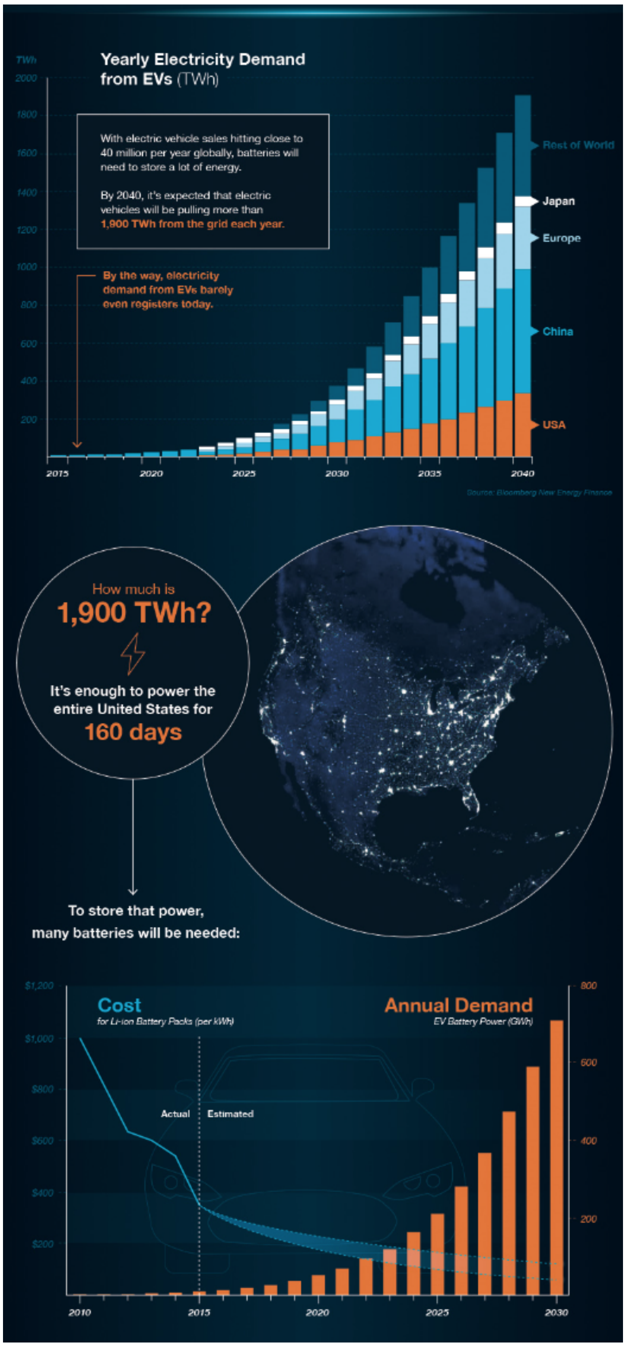


Figure 5 Expected Electricity Demand from EVs [31]

According to several consumer surveys, the amount of charging stations available heavily influences their buying behavior [34,35,36]. When visualizing the amount of charging points, it is important to not only show the total number (as in figure 6 below) but also its density when comparing the individual countries (Figure 7).

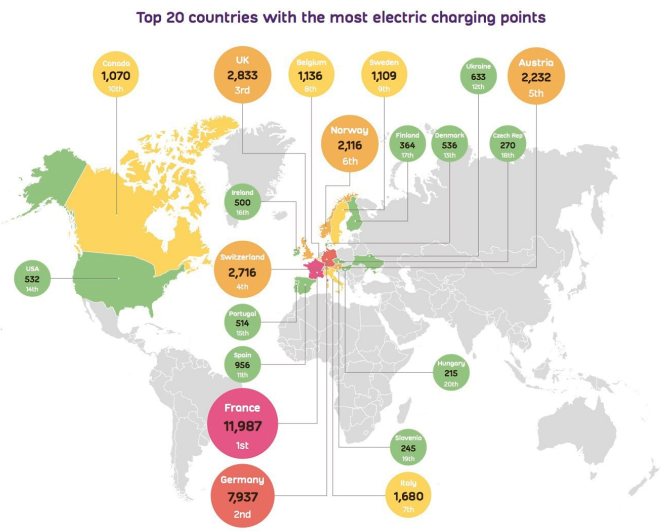


Figure 6 Top 20 countries with the most electric charging points 11/2017 [37]

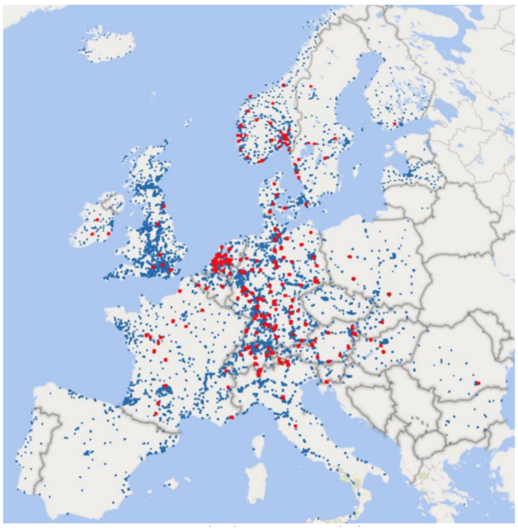


Figure 7 Distribution of CCS fast (blue) and CCS ultra-fast (red) public charge points [38]

2.2.1.3 Influence of politics on Emobility

Politics do have a significant influence on the rise of Emobility. It is estimated that fines for major car makers will add up to 14.5 billion euros because all of them are set to miss their 2021 targets [40].

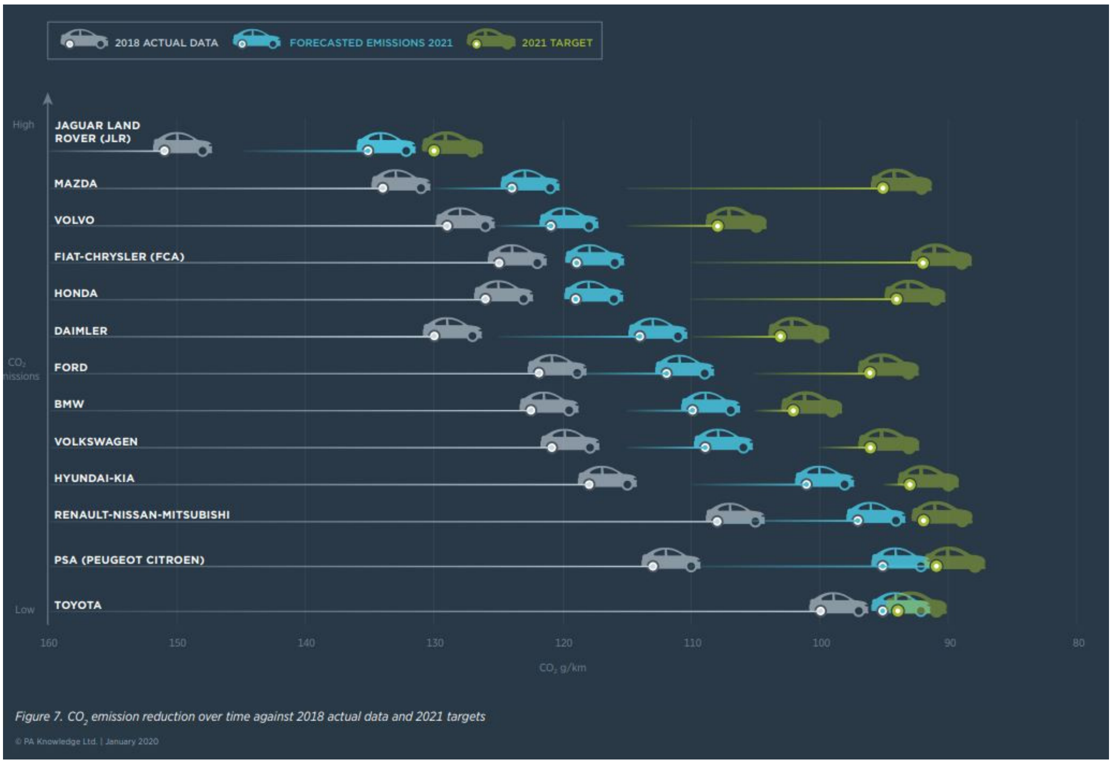


Figure 8 CO2 emission reduction over time against 2018 actual data and 2021 targets [40]

But while politics do put pressure on automakers, they also have a big influence on the buying behaviour of the consumers. JRC scientists carried out a pairwise comparison of total operating costs and electric car sales in eight European countries - France, Germany, Italy, Hungary, the Netherlands, Norway, Poland and the United Kingdom - to assess and evaluate how different financial incentives may have stimulated car sales [41].

2.2.1.1 E-Mobility Overview

In most research papers and websites, single data sets are presented, and it is hard to understand Emobility and the shift to EVs as a whole. Emobility is a complex topic and affects several sectors and research areas. Visualizing only one data set is therefore not sufficient to inform about it. There are several approaches possible when presenting more than one data set. They can either be visualized separately (As can be seen in Figure 9) or several parameters together in one visualisation (Figure 10). Hubject has published the so called HEMI [43], which is a detailed analysis of the electric mobility market in 31 European countries. Several indicators have been calculated which resulted into the so called Emobility Market Index score. Based on this score, the “Top Emobility Countries” have then been presented (Figure 11)

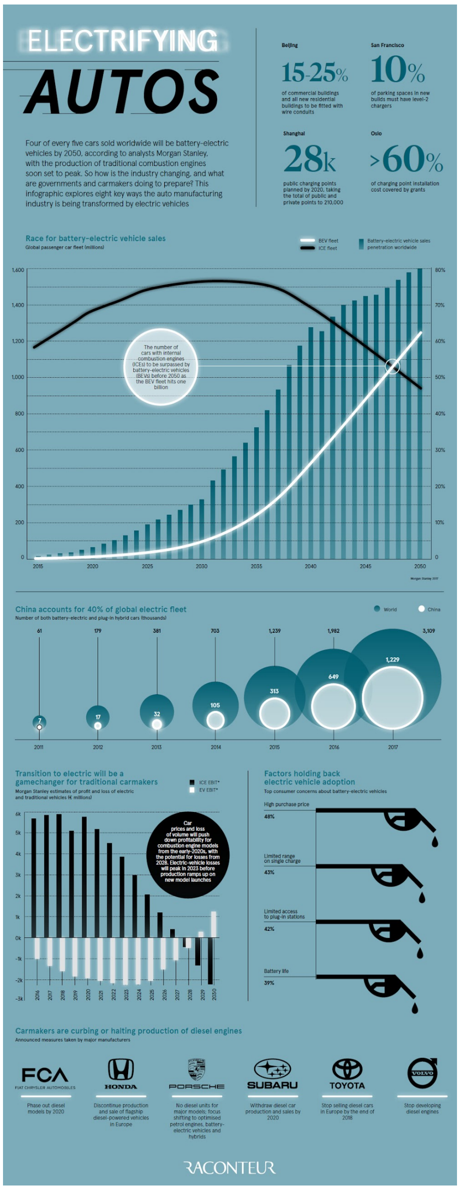


Figure 9 “Electrifying Autos” [42]

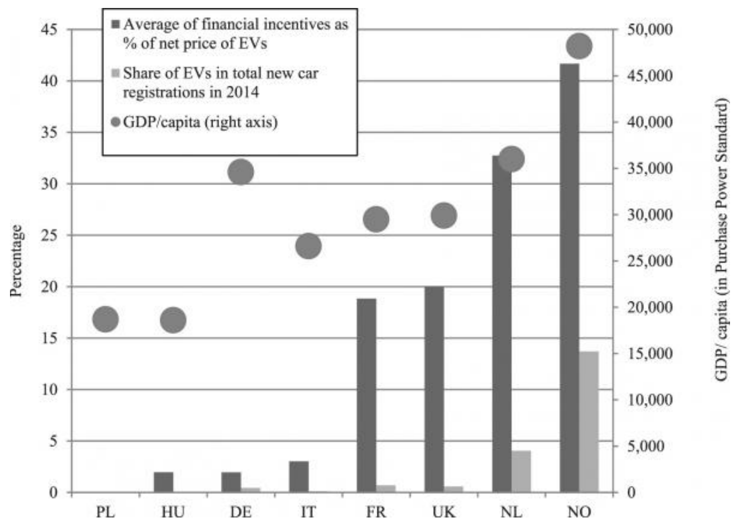


Figure 10 fiscal incentives how do they impact electric vehicle sales [41]

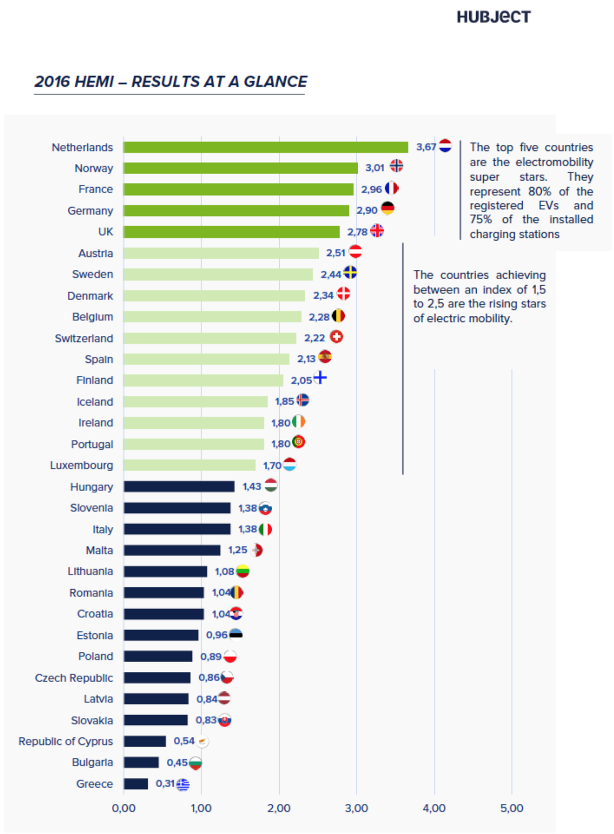


Figure 11 2016 HEMI Hubject [43]

2.2.2 Other related topics

A lot of topics are directly related to Emoblity and can, therefore, be used as inspiration for creating the data visualizations. Below, some findings are presented which were either considered good and creative executions or which are based on data sets that are by type similar to the ones from Emobility.

2.2.2.1 Autonomous vehicles

According to V. Dupray, the three main mobility trends of the automotive industry are autonomous, electric and shared cars [44]. Autonomous cars do have big overlaps with private EVs as they rely on the same infrastructure and also require consumer acceptance as well as the development of new technology to grow in sales. As there are many influences on the rise of autonomous vehicles, an interactive approach as can be seen below in figure 12 makes sense.

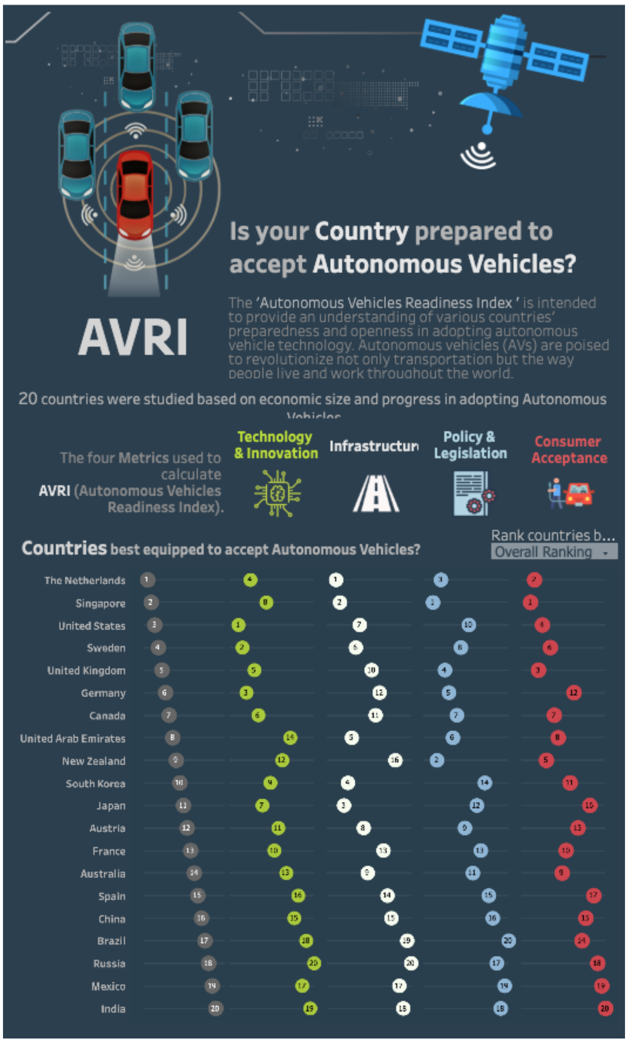


Figure 12 Interactive Data Visualisation showing the countries best equipped to accept autonomous vehicles. Several filters can be applied.[45]

2.2.2.1 Energy

Becoming the world's first climate-neutral continent by 2050 is the goal of the European Green Deal, the most ambitious package of measures to enable a sustainable green transition [46]. The switch from fossil-fuelled cars to electric vehicles is only then effective in regard to lowering the CO2 emissions, if the energy which is used to charge them is mainly from renewable sources.

A visualization that sets the share of renewable energy sources in relation to the respective goals of the EU member states (figure 13) as well as the changes in the global energy mix (figure 14) can be seen below.

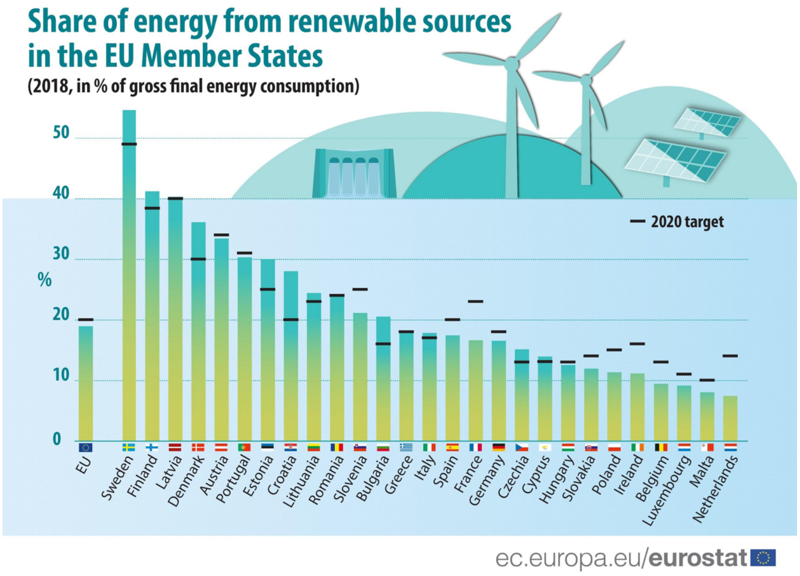


Figure 13 Share of energy renewable sources in the EU member states 2018 [46]

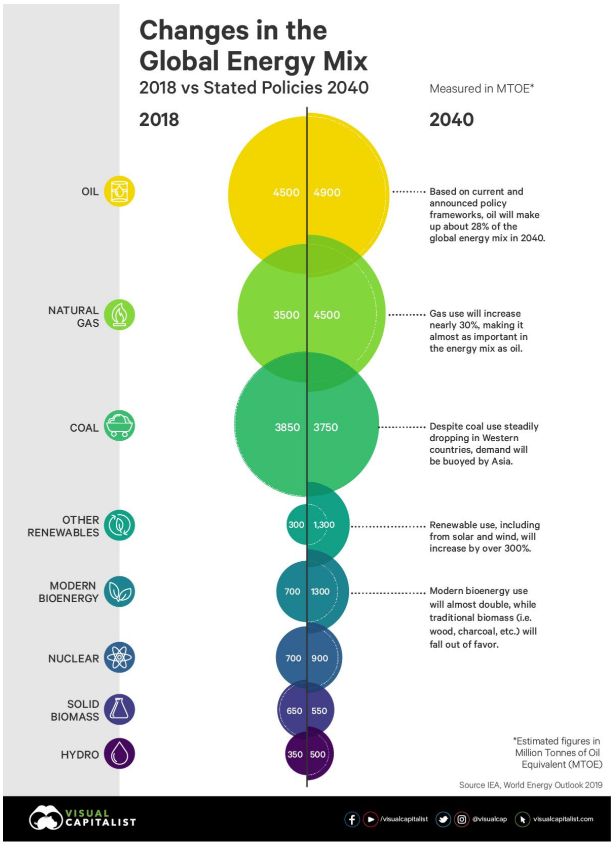


Figure 14 The World’s Projected Energy Mix, from 2018-2040 [47]

2.2.2.1 Infrastructure

For the successful implementation of a charging network and the success of Emobility, it is important to understand the general infrastructure and travel behaviour of vehicle users. Even though a lot of people consider range anxiety as one of the top reasons why they hesitate to switch to an EV [34,35,36], 90% of cases in high-income countries, which are concentrated in Europe and North America, live within one hour of a city [48]. With exact geographical data, heatmaps and densitymaps can be useful tools to showcase the travel distance (figure 15) as well as the density of the infrastructure (figure 16).

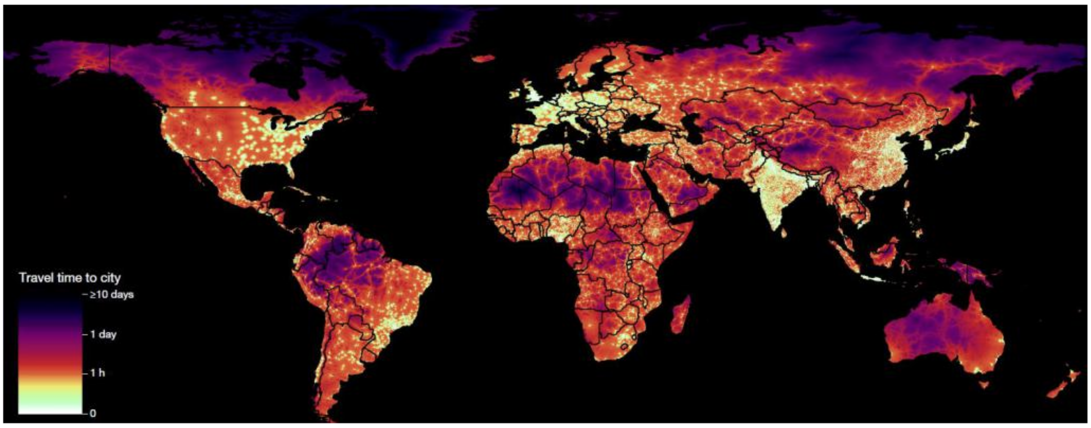


Figure 15 Travel distance between cities [46]

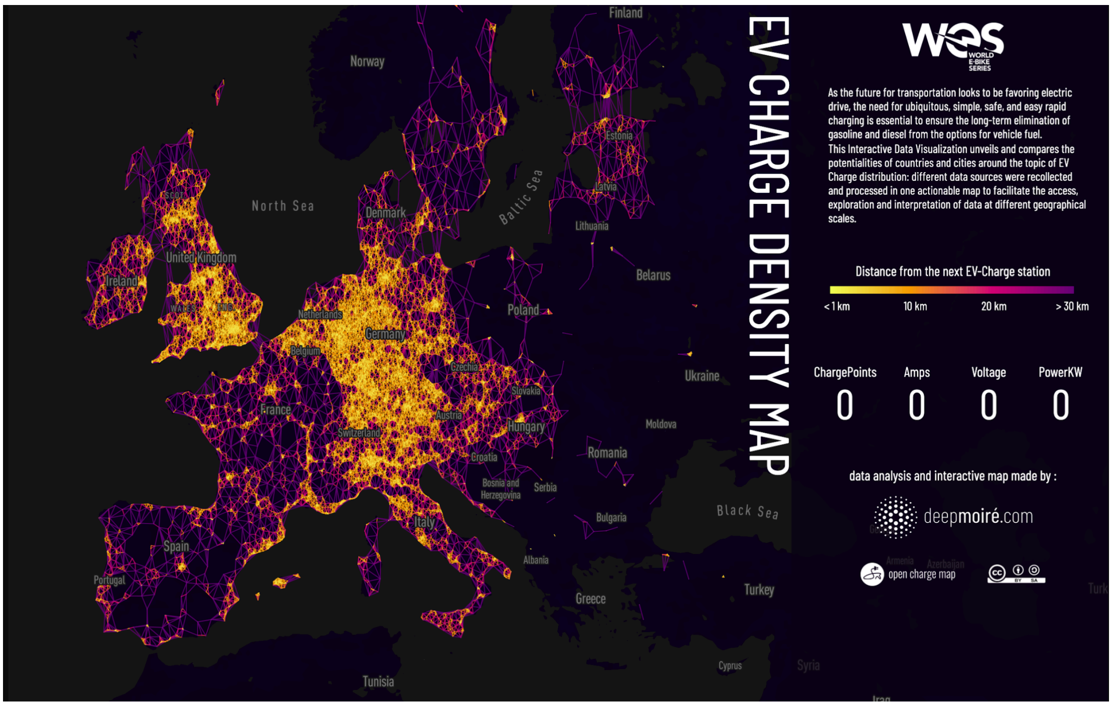


Figure 16 EV Charge density map [49]

2.2.3 Conclusion

In most research papers, only column charts or histograms are used. But some interesting and creative data visualisation approaches have been found as well. The most common types of visualisations are listed in table 1 below, together with their respective use cases:

Type of Visualisation	**Use Cases**
Column Chart and Histogram	Used especially in research papers. For almost all data sets.
Stacked Bar Graph	Comparing current data to future goals, i.e. CO2 emissions and its targets
Line Graph	Showcasing the rapid development of charging stations, the decrease of the battery price or comparing the sales of fossil fuel cars with EV cars
Heat map	Travel distance between cities,
Sankey Diagram	Financing Climate Goals
Bubble Chart	Comparing the worlds growth of EVs available on the market with a single country,Comparing current data of the global energy mix with outlooks, Charging stations per country
Density Map	Charge station density
Infographic	To show correlations and provide an overview of eMobility in general

Table 1: Type of Data Visualisation and their use cases

The biggest problem with the visualizations found outside of research papers is that the source of the data sets is not always clear, and a lot of visualisations are already outdated. Also, there is a very limited number of actual infographics available, which shows the bigger picture of Emobility and correlations between the different data sets.

It is important to always show the data within the context. From showing for example only the amount of charging stations per country, one cannot directly conclude if a country is “ready” for Emobility as this depends on other factors such as the ratio of EVs to charge points and the size of the road network as well.

3 Method

This section will describe what was done to answer the research question, describe how it was done, justify the design and explain how the results were analysed.

A landing page was chosen as the platform to present the visualizations. This was done for several reasons:

1. This project can be combined with the project of Gleb Podorozhnyy to provide a comprehensive overview of the current state of Emobility as a whole. This was one of the main requirements of the client.
2. The individual data visualizations can be connected through a story and additional data and facts can be presented to show the visualizations within the appropriate context
3. The website is accessible to everyone and can easily be shared. This is an important factor as one main purpose of the project is to educate people about the current state of Emobility.
4. The Hubject website can directly be linked from the landing page, leads can therefore be generated to the Hubject website
5. Hubject will be able to update the respective data sets and keep the content up to date with ease.
6. Shareable assets of the visualizations can be offered to download in exchange for data such as email address and name so that possible new leads can be generated at a later stage.

The tasks for the design and development of the landing page have been divided between Gleb and me as displayed in figure 17 below.

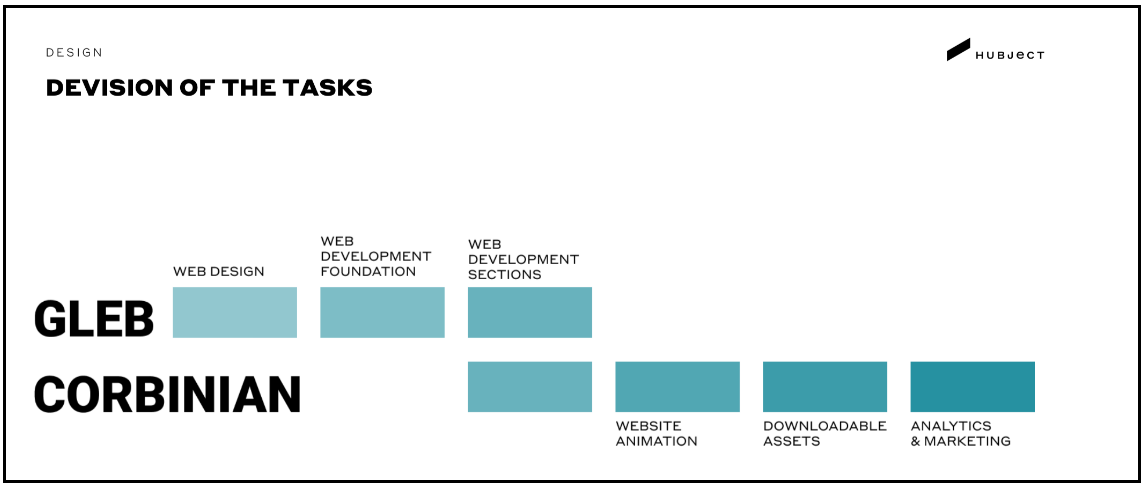


Figure 17 Division of the tasks

Gleb Podorozhnyy has worked on the general web design of the landing page as well as on the foundation of the web development including the menu structure, introduction and outlook section. He has also created a wireframe for the individual sections. Based on the wireframe, I have then developed my respective sections and animated the website to enhance the user experience. Downloadable assets have been created to be shared across social media channels by the visitors of the website. Finally, analytic tools such as Google Analytics and Hotjar have been implemented to evaluate the success of the project in regard to the marketing effectiveness.

3.1 Tools

In order to successfully complete this project, several tools have been used which are grouped in categories in table 2 below.

Design & Brainstorm	Animation	Interactivity and technical implementation	Web Development	Testing
Figma	Adobe After Effects with Lottie	jsfiddle	Webflow	Google Forms
Adobe Illustrator		HTML		Google Analytics
Excel		CSS		Hotjar

		Javascript		

Table 2 Overview of tools which have been used in this project

3.1.1 Figma

Figma is an interface design application that runs in the browser. This makes it a very useful tool for collaboration as several users can work on a project simultaneously. With the option of leaving comments on the designed wireframes it is also a great tool for giving and receiving quick feedback from all involved stakeholders. This tool was mainly used in the brainstorm phase to create the first static visualizations as well as for the UI (User Interface) design of the website on which the visualizations will be published.

3.1.2 Adobe Illustrator

Adobe Illustrator was used to layer the single elements of the exported Figma Visualization in a correct way so that they could be animated in Adobe After Effects afterwards. The software was also used to create the downloadable social media assets as well as the PDF (Portable Document Format) version of the website.

3.1.3 Excel

Excel is a spreadsheet program, a data visualization and analysis tool. It was mainly used to sort and structure the data sets. It was also used in the converging design phase as it provides a quick overview of which basic visualizations are possible and useful and which not.

3.1.4 Adobe After Effects in combination with the Lottie Plug-In

To animate some of the visualizations, Adobe After Effects has been used. The software is a digital visual effect, motion graphics and compositing application that can be used for keying, tracking, compositing and animation. The Lottie plug-in by Airnbnb is an iOS, Android and React Native library that renders After Effects animations as json codes so that they can easily be implemented into the website.

3.1.5 jsfiddle

JsFiddle is a code editor that lets you test your JavaScript, CSS, HTML or CoffeeScript online and allows the export as an iframe format - which gives the ability to implement the code directly into the website. This editor was used to create the interactive Sankey diagram.

3.1.6 Webflow

Webflow is a web design tool, CMS and hosting platform that translates design decisions into clean, production-ready code. This software was used for the reason that it supports all visualization output files (iframe and json) and it is possible to create a rather complex website with custom animations and interactions.

3.1.7 Google Forms

Google Forms is a survey administration app and was mainly used to create surveys in the prototype phase to get feedback on the static visualizations.

3.1.8 Google Analytics

To analyse website traffic and the user behaviour on the website, Google Analytics will be used. Google Analytics is a free web analytics tool offered by Google and will collect data on four levels:

- User Level (related to its actions)
- Session Level (for each individual visit)
- Pageview level (for each individual page)
- Event level (button clicks, downloads, video views etc)
-

3.1.8 Hotjar

Hotjar is a website heatmaps and behaviour analytics tool. Several tests will be executed using this software:

- depth (how many users scrolled beyond the fold)
- link (how many users click on links or elements which are mistaken as links)
- header (how many people are engaging with the navigation

3.2 Design workflow

Below, an overview of the design process which will be used for this project can be found. All steps will be outlined in detail in this chapter.

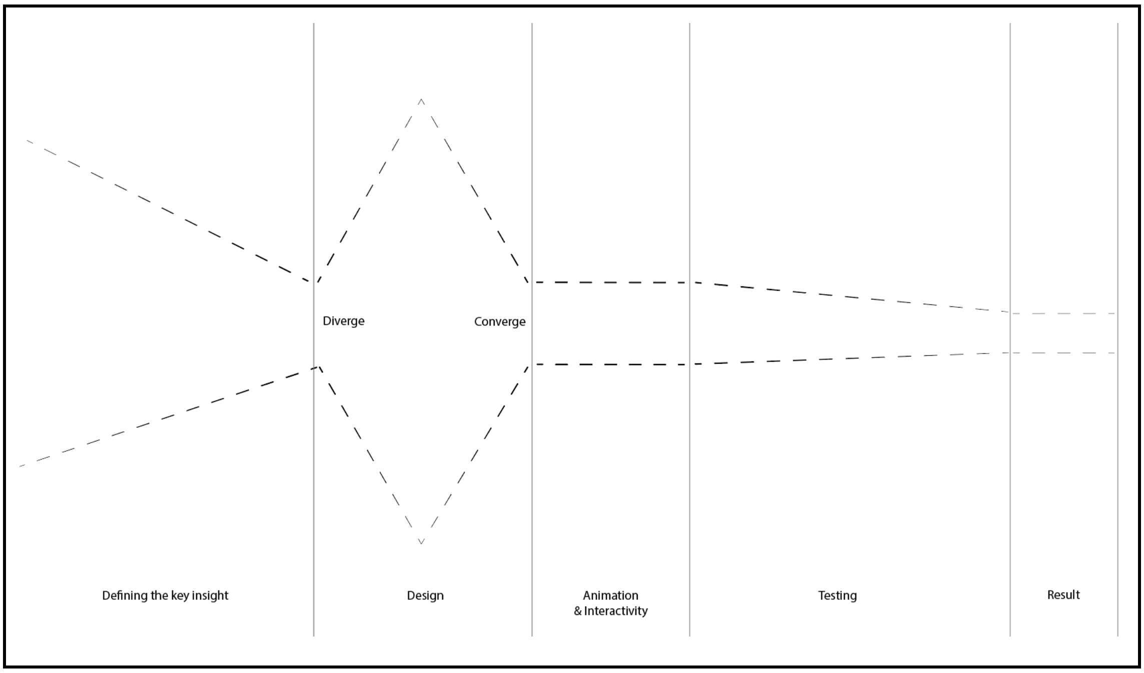


Figure 18 Method workflow

3.2.1 Definition of the key insight

Defining the key insight and what message the visualization should convey is the first step in the process. As the infrastructure of Emobility is a complex topic and affects a lot of different areas it has to be ensured that the research question and its sub questions will be answered with the respective execution. If the designed visualization successfully communicates the respective key insight will later be tested in 3.2.4.

3.2.2 Design

The general design has been oriented towards Hubject's visual identity system (See figure 19 below) as this has been one of the requirements by the client. The respective primary brand colours have been used to represent the different sections of the landing page. Only the Hubject cool grey 100 was slightly adapted to a darker tone for contrast reasons. The two sections infrastructure and technologies are both topics from this part of the project, the other two sections and their respective visualizations have been developed by Gleb Podorozhnyy.

Figure 19 Hubject´s primary colors and the choice of colors for the sections of the landing page

For each visualization, the design phase will happen in two sequences: diverging and converging of solutions. According to Brown [1] in the diverging phase, choices are created, while in the converging research, choices are made (see Figure 20 below).

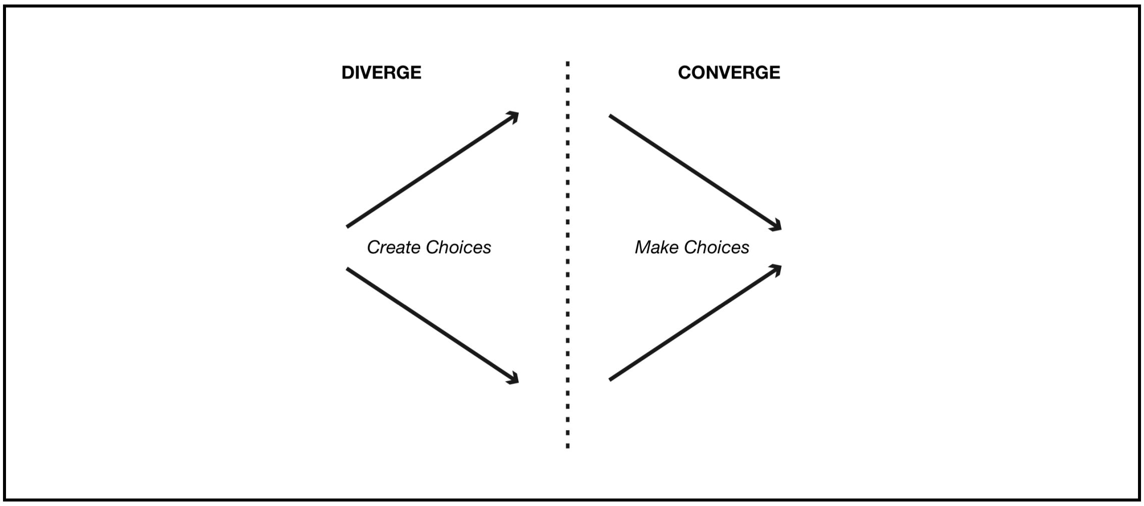


Figure 20 Diverging and converging in design thinking, adapted from Brown [51]

By following this approach, firstly many different ideas will be generated going into different sections. In the second phase, these ideas will be combined, and some may be left out until coming together to one final idea. In this step it will also be outlined what data has been used.

3.2.3 Animation/Interactivity

When the static version of the visualization has been designed, possibilities for animations and/or interactivity will be explored. If the static version by itself needs information on different levels to be understood, interactivity can be a solution. As the final visualizations will be integrated into a web application, they have to be coded as <iframe> to keep their interactive properties. An inline frame is used to embed another document within the current HTML document and is supported by all common web browsers.

To make the visualizations visually more appealing and interesting for the viewer, they will be animated if they are not already responsive. It has to be ensured that the animation does not influence the understanding of the key insight which the visualization communicates. Adobe After Effects will be used as a tool, together with the Lottie Plug-In, to be able to export and integrate the animation into the website as a json code.

3.2.4 Testing before launch

Several initial test methods will be used throughout the execution of the project. Those will be explained below.

3.2.4.1 General survey of the public

Together with the first working prototype, a survey will be distributed among randomly selected people. The survey will include both open questions to collect personalized feedback and comments for the design choices, as well as closed questions to be answered on a five-point Likert scale. Each visualization will be tested separately as well as the overall look and feel of the entire landing page. Additionally, it will include some personal questions such as age, if they are students and if yes, what is their study. This way, it can be analysed if there is any correlation between those indicators and the perception and understanding of the visualization. The main goal is to determine if the visualizations are clear and meaningful as well as if the design is attractive.

3.2.4.2 Qualitative user testing with a focus on responsiveness

As the landing page should be accessible on all devices, some content and data visualizations might need adjustments to fit the respective format. Especially readability and interactivity will be tested. This will happen through a remote moderated usability test. 5 users will be tested via Skype Sessions. During the test, the participant will be asked several questions regarding the general appearance of the visualization. Some additional questions will be asked to verify the understanding of the visualization as well as to test the interactivity (if applicable).

3.2.4.3 Survey for experts of the field

After the feedback of the survey mentioned in 3.2.4.1 has been implemented together with the adaptions to fit all screen sizes 3.2.4.2, a copy of the same survey will be distributed among people who work in companies within the industry. As those are all experts in the field of Emobility, the main purpose of this survey is to find out if sufficient data has been provided to showcase the current state of Emobility.

3.2.5 Refinement and implementation

After the initial user test and feedback, the visualizations will be refined and developed again. Then, they will be published and tested for errors from the local developer environment. After the entire website has been reviewed by the team, the website can be set live and new test methods can be used to evaluate the success of the project.

3.2.5 Testing after launch

3.2.5.1 Google Analytics

The moment the visualizations are online and accessible by the public, Google Analytics will be used as a testing tool. The user engagement as well as the user satisfaction will be measured using the following key metrics:

- Length of page visit (How interesting is the content?)
- Number of asset downloads (Is the content worth to share?)
- Number of leads from the Emobility page to the Hubject page (Does the content make Hubject a thought leader of emobility?)
- Page views per session

3.2.5.2 Hotjar Heatmaps

As the structure of the landing page is one long website with several sections, a scroll heatmap can be used to analyse, how far the users have scrolled. This gives conclusions how interesting the content is to the visitors.

With the click heatmap one can determine whether all interactions are clear and how often they interact with the visualizations or buttons. This will especially provide information on the user experience (UX) design.

4 Execution

To visualize the current state of Emobility infrastructure, in total, five visualizations have been created regarding the following three topics:

- The distribution of charge points
- Charging Speed of EVs
- Range of EVs

For clarity, information will be presented in sub sections according to the topic. For the creation of the visualizations, the design workflow was followed as explained in the method 3.2.2.

4.1 The distribution of charge points

More than 1.5 million EV chargers have now been installed in parking garages, shopping centres, businesses, homes and other locations around the world.[52] This number is projected to grow rapidly, with more than 60 million chargers expected to be installed by the end of 2029 [53].

4.1.1 The distribution among the world

4.1.1.1 Definition of the key insight

The network does not develop equally among the world. In China for example, the government promotes electric vehicles with several policies including subsidies, rebates, quotas and tax exemptions for vehicle manufacturers. In September 2017, the Ministry of Industry and Information Technology put his new one energy vehicle quota (NEV) in force that requires all automakers with over 30,000 annual vehicle sales in the country to produce 10% EVs in 2019 and 12% in 2020. This has ultimately led to the world's biggest charging network up until now. In 2018, more than half of the charge points were installed in China alone [54]. To get a first impression about how the charging network is spread around the world, the corresponding data visualization should therefore display the total amount of installed charge points within certain geographic areas.

Another value to look at is the amount of slow and fast chargers within that network. A high share of fast chargers would remove a significant barrier to the adoption of EVs as the time scale to charge the batteries will be similar with the time to fuel an internal combustion engine vehicle (ICEV) [55].

The visualization should therefore consist of two data sets: The number of public chargers per country or geographical area and the share of slow and fast chargers. The data has been taken from the Global EV Outlook [54] as this source contained the most complete data set. As the country specific data differs slightly among the sources, it was decided to rather use this source from 2018 than using more recent data from several different sources.

4.1.1.2 Choice of Design

To visualize both the total number of charge points as well as the share of slow and fast chargers, it was decided to use a Sankey diagram as one can interpret it fast and understand where and what kind of charge points are installed worldwide. To also provide the viewer with more details, the Sankey diagram was coded in such a way that the viewer can interact with it. When hovering above a flow that represents a country, it provides the exact number of charge points or the number of fast charge /slow charge points respectively.

The visualization was created in the online code editor jsfiddle. This way it was possible to test the code, which consists of JavaScript, CSS and html, before embedding it to the website. As a library, Google Sankey Chart was used. Through custom JavaScript and CSS, the code was modified to match the design guidelines. One other big advantage of using jsfiddle is that when updating the code from the jsfiddle user account with newer data, it will automatically get updated on the website as well. The code which has been used to create the Sankey diagram can be found in appendix 1.

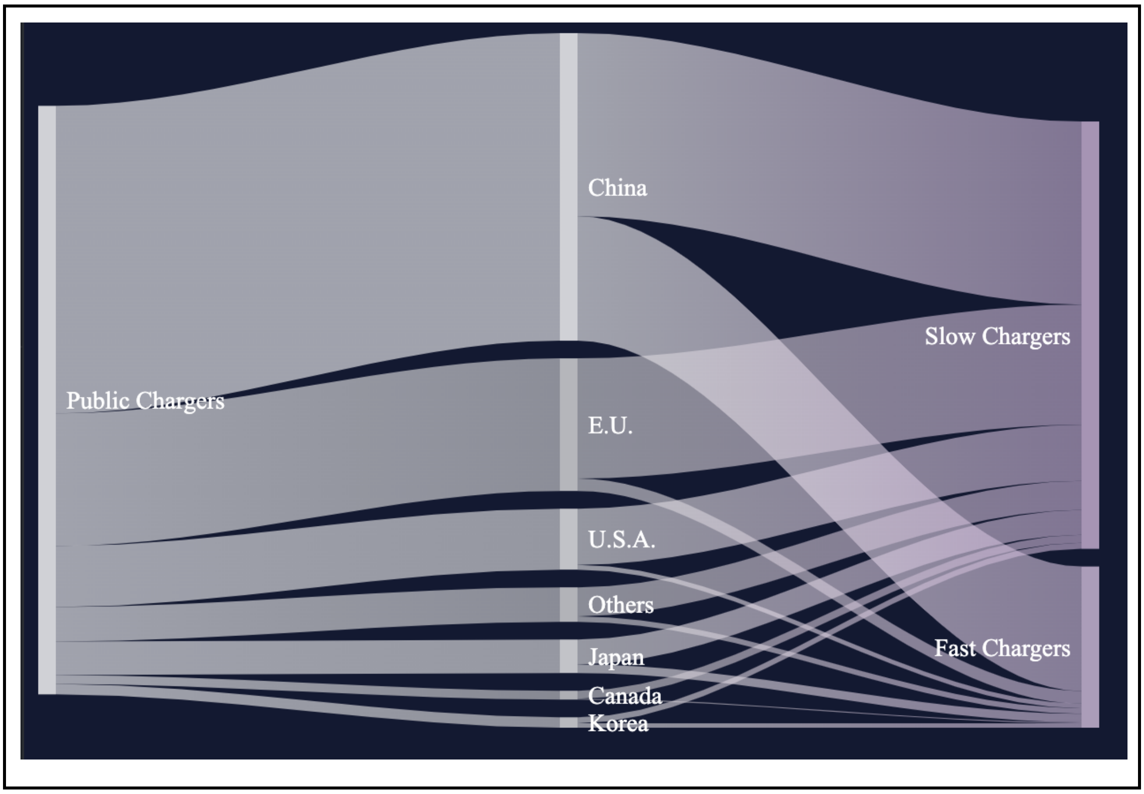


Figure 21 Public EVSE chargers by country and type 2018

4.1.1.3 Testing and results

The design has been tested using a Google Form as explained in section 3.2.4.2. The survey can be found in Appendix 2. The form was spread among seventeen students and non- students between 18 and 34 years old. Most questions have a Likert scale as an answer with 1 being “strongly disagree” and 5 being “strongly agree”. Some of the outcomes are displayed in table 3 below:

Topic regarding the question	Average answer from 17 surveys
Text and numbers are clearly visible	4.3
Easy to understand	3.4 / 4
Clear purpose	4.2
Aesthetically pleasing	4.1
The visualization is interesting	4.3
Key insight matches the understanding	3.4 / 4.1

Table 3 Results of the general public survey for Visualization 1

The first four answers of the two questions regarding the understanding of the visualization and the key insight had to be removed and the previous result (marked red in table 3 above) had to be recalculated. During the creation of the survey, the copy and the key insight referred to one of Gleb's visualizations regarding purchase interest and has not been updated accordingly.

In general, the visualization seems to be widely understood by the general public. One remark that was recorded was that the font does not match the typefaces used on the landing page.

As explained in 3.2.4.3, a responsiveness test was performed as well. The five testers have successfully completed the challenges and did not have problems with the interaction of the visualization. For the responsive version of the visualization, only half of the data is shown initially, with the possibility of scrolling to the right to see the share of slow and fast chargers per country.

4.1.1.4 Design Refinements

The html code has been updated so that the text is displayed in the font "Styrene A", which is one of the two primary fonts of Hubject's brand identity system. The updated code can be obtained from Appendix 1.

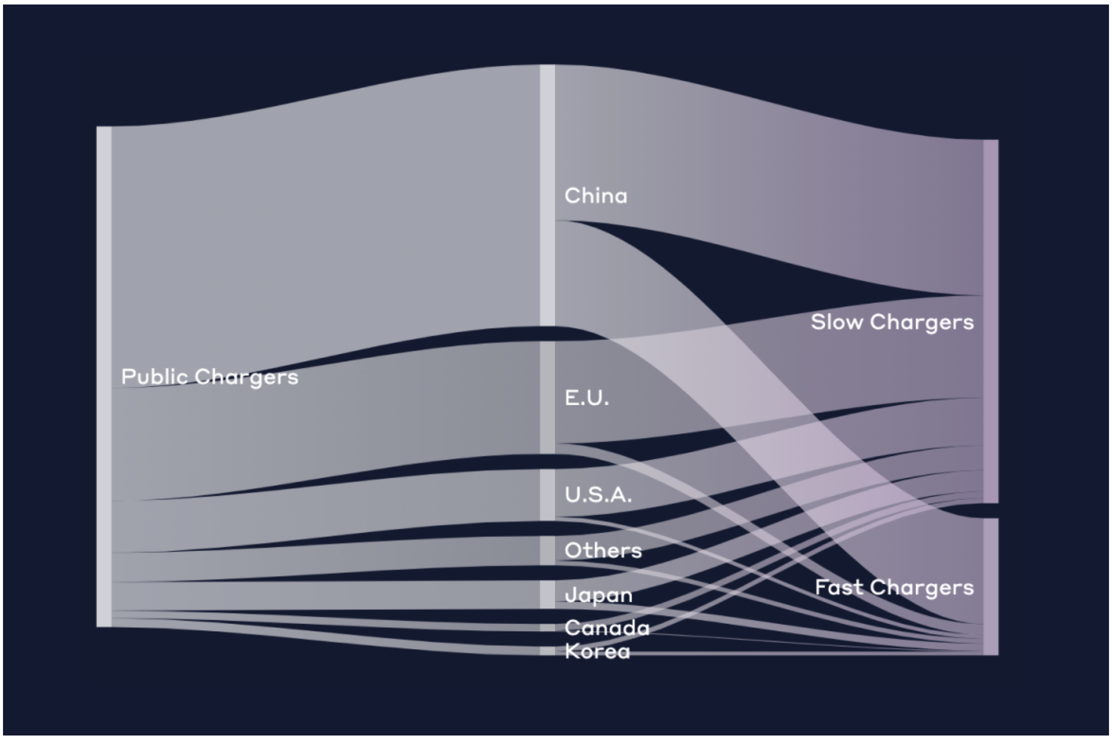


Figure 22 Updated visualization of the Public EVSE chargers by country and type 2018

4.1.2 The distribution of charging networks among the EU states

4.1.2.1 Definition of the key insight

Even though the total number of charge points per country is the most common indicator showcasing the state of infrastructure, other factors also have to be taken into account. When setting the charge points in proportion to the population for example, one can clearly see that the two nations with the most charge points installed suddenly fall far behind, and ,other, smaller countries such as Norway and the Netherlands are leading in the statistics (see Figure 23 below).

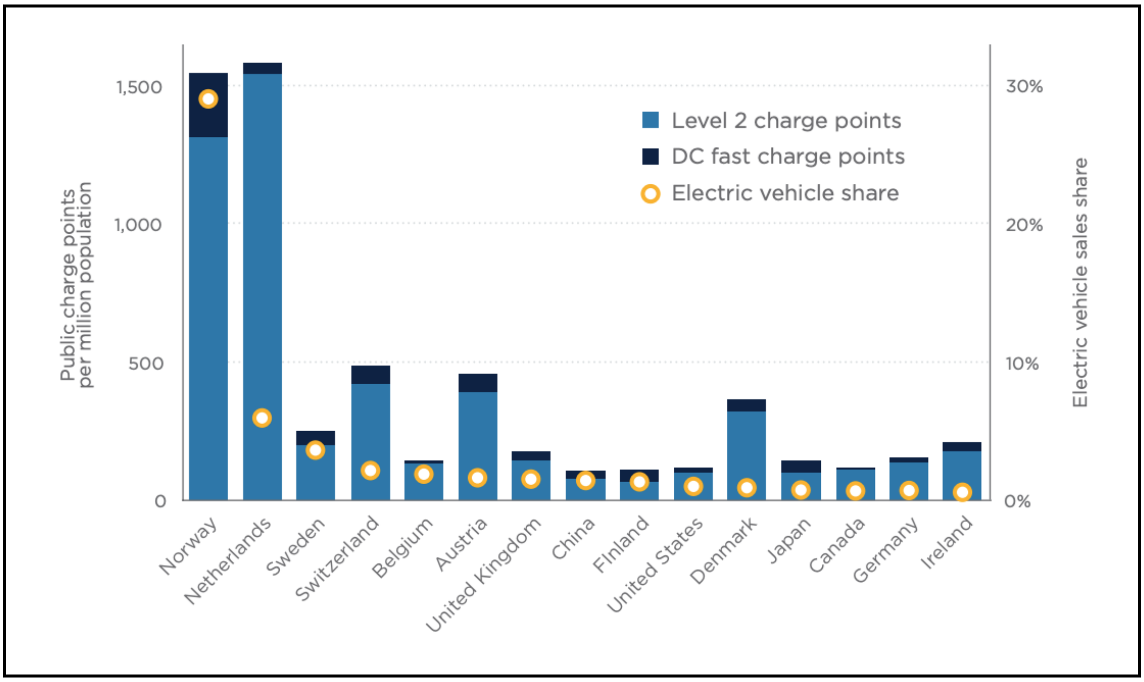


Figure 23 Public charge points per million population and Electric vehicle sales share [6]

As most of the website visitors will probably be from Europe (The majority of Hubject's clients is from Europe), it is important to not only show the total number of charge points of all European countries but providing a more detailed representation of the current state of Emobility infrastructure including several key indicators.

The number of charge points in the European Union is growing rapidly, almost exponentially. With only 400 normal charge points in place in 2010, there were almost 150.000 normal and more than 15.000 fast charge points installed by the end of 2019 [56]. The EU plans to have 1.3 million public charging stations by the year 2025 and 3 million by 2030 [57].

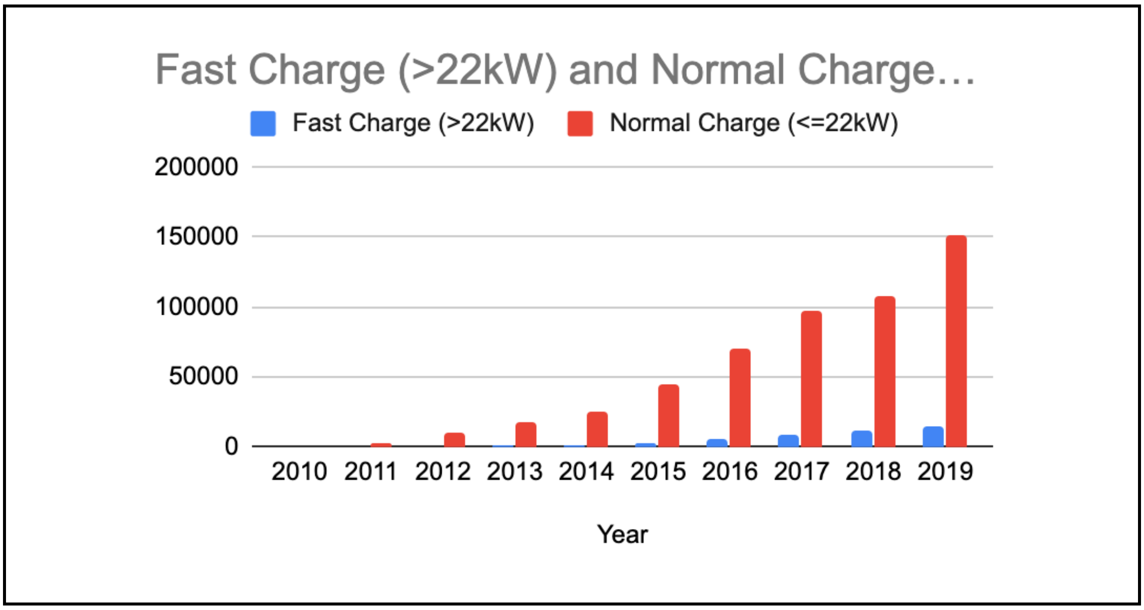
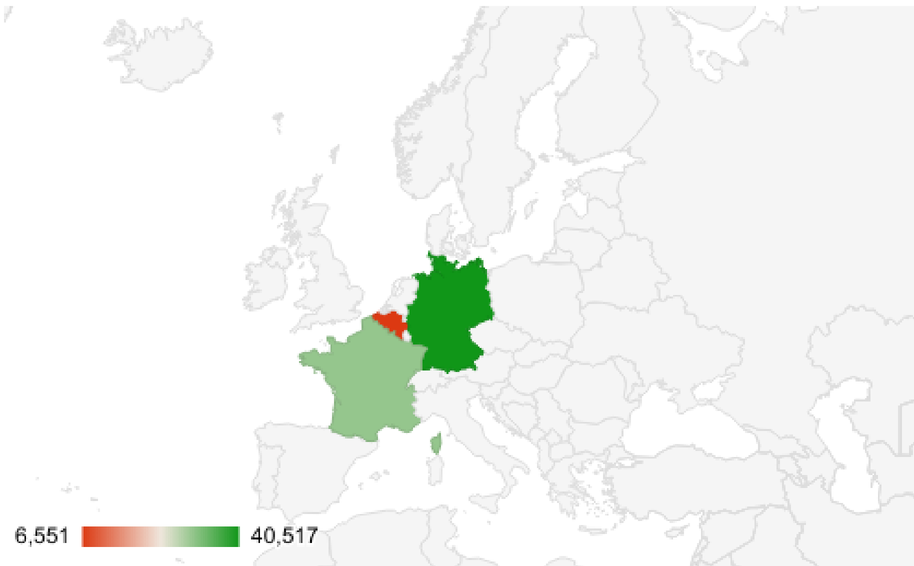


Figure 24 Normal and fast public charging 2010-2019 in the EU [56]

But when looking at the individual countries, this number is just one factor and is not a meaningful and truthful indicator of the state of Emobility on its own. As explained above, a higher number of charging stations does not necessarily mean that a country is better prepared for the shift to Emobility.

A factor which should be taken into account is for example the ratio of electric vehicles to charge points. If there are more than 10 EVs per charge point, the given network is, according to the EU recommendations, insufficient. Other factors are for example the density of the network and how strategically the charge points are located. To cover longer distances for example, placing the charging stations among highways is key. Therefore, including the amount of charge points per 100km highway into the statistics, could improve the truthfulness of the state of Emobility in regard to infrastructure per country.

Below an example of how the different data sets provide a completely different picture in regard to Emobility for the selected countries. Comparing the neighbouring countries Germany, Belgium and France, one can clearly see that Germany has the most charge points installed, followed by France and with Belgium the last.

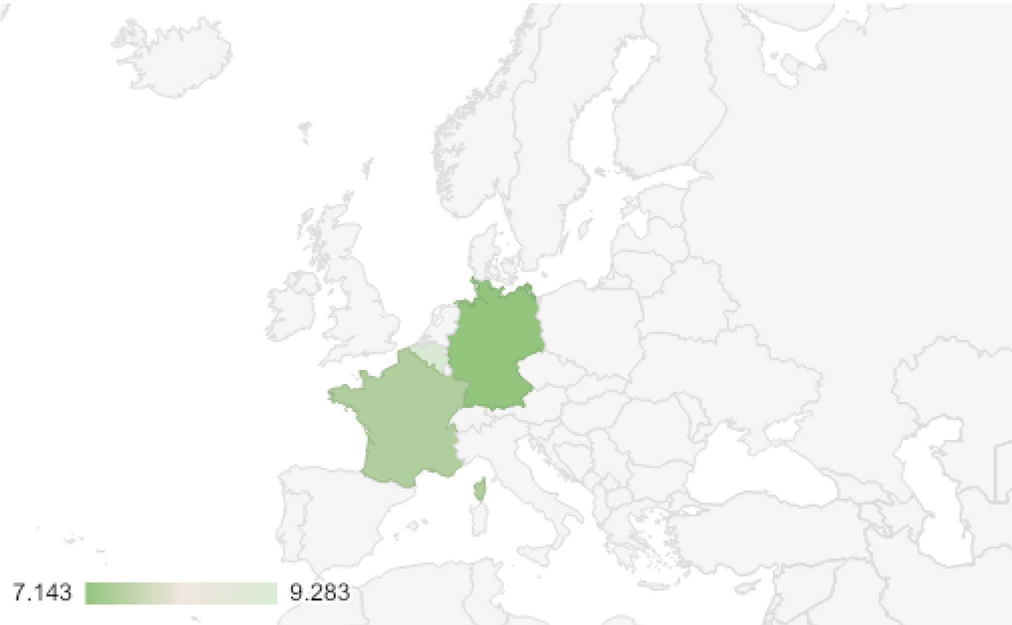


Country	Electricity Charge Points
Belgium	6551
France	30367
Germany	40517

Figure 25 Number of electricity charge points installed in Belgium, France and Germany with its respective data set.

But when looking at the ratio of registered EVs per charge point it becomes clear that all three countries have a ratio of less than 10 EVs/charge point, which, according to the European recommendation, is a sufficient amount. If the number of registered EVs compared to the installed charge points is high, this would result in most charge points being occupied, which ultimately lead to a low driver satisfaction and a weak infrastructure.

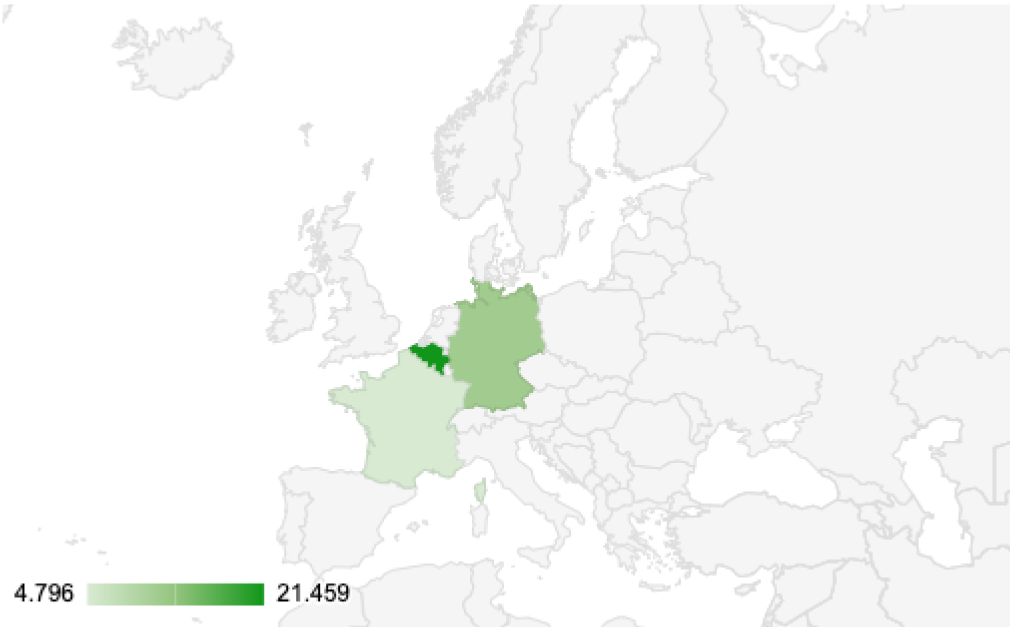
Comparing the data visualization from the charge points before, we can see that the order of the countries remained the same, with Germany having the least cars per charge point, directly followed by France and with Belgium last, having almost two more EVs registered per charge point. However, the respective values are much closer to each other and all three countries have a ratio of less than 10 EVs registered per ChargePoint.



Country	Vehicles/charge point
Belgium	9.283468173
France	7.487766325
Germany	7.142557445

Figure 26 Number of registered vehicles per electricity charge points installed in Belgium, France and Germany with its respective data set.

Another important factor when comparing the total amount of charging stations, is the respective size of the specific countries. Therefore, the average number of charge points per 100 square kilometres was calculated which led to an interesting result: Belgium has by far the highest number of charging stations with more than 20 installed per 100 square kilometres, Germany follows with 11 stations and France becomes last with only 4 charging stations.



Country	charge point/100 square km
Belgium	21.45898847
France	4.795900608
Germany	11.33735897

Figure 27 Number of charge points per 100km2 installed in Belgium, France and Germany with its respective data set.

As it can be clearly seen in the examples above, the total number of charging stations per country alone is not a sufficient parameter in showcasing the Emobility infrastructure. To show all three visualisations within the story gives the visitors a clearer picture where there is a need to invest more into Emobility: For example, where to install more charging stations (This can be a first mover advantage for charging network providers). For other visitors, those visualizations contain also interesting insights, as they can evaluate if it already makes sense to invest in an electric vehicle in their area, especially if they are planning to do a lot of distance traveling.

In total, three different data sets were considered to visualize the distribution of charging stations in Europe. The European Alternative Fuels Observatory provided the data for the total amount of charge stations per European country as well as the number of EVs registered in each country. Based on those values, the ratio of EVs/charge stations was then calculated and used as the data set for the second visualization. For the third visualization addressing the amount of charging stations installed in comparison to the country's size, geographical data from the data world bank [70] has been used.

4.1.2.2 Choice of Design

As the main goal of this data visualization is to show the current state of infrastructure in different geographic areas, a map chart has been used. To be able to show the state of infrastructure based on different measuring methods, it was decided to have an interactive visualization where the visitor can directly compare the data of total amount of charge points, charge points per 100km2 and EVs registered per charge point by clicking on the respective buttons. When hovering with the mouse above a certain country, the exact number appears together with the name of the country. Some additional key information is also displayed next to the legend.

The visualization has been created directly in Excel. After the modification to match the design guidelines, it was then embedded as an interactive version and combined with the other two visualizations as an iframe code into webflow. The big advantage of this implementation is that the code is linked to the Excel sheet directly and can therefore be updated live and anytime.

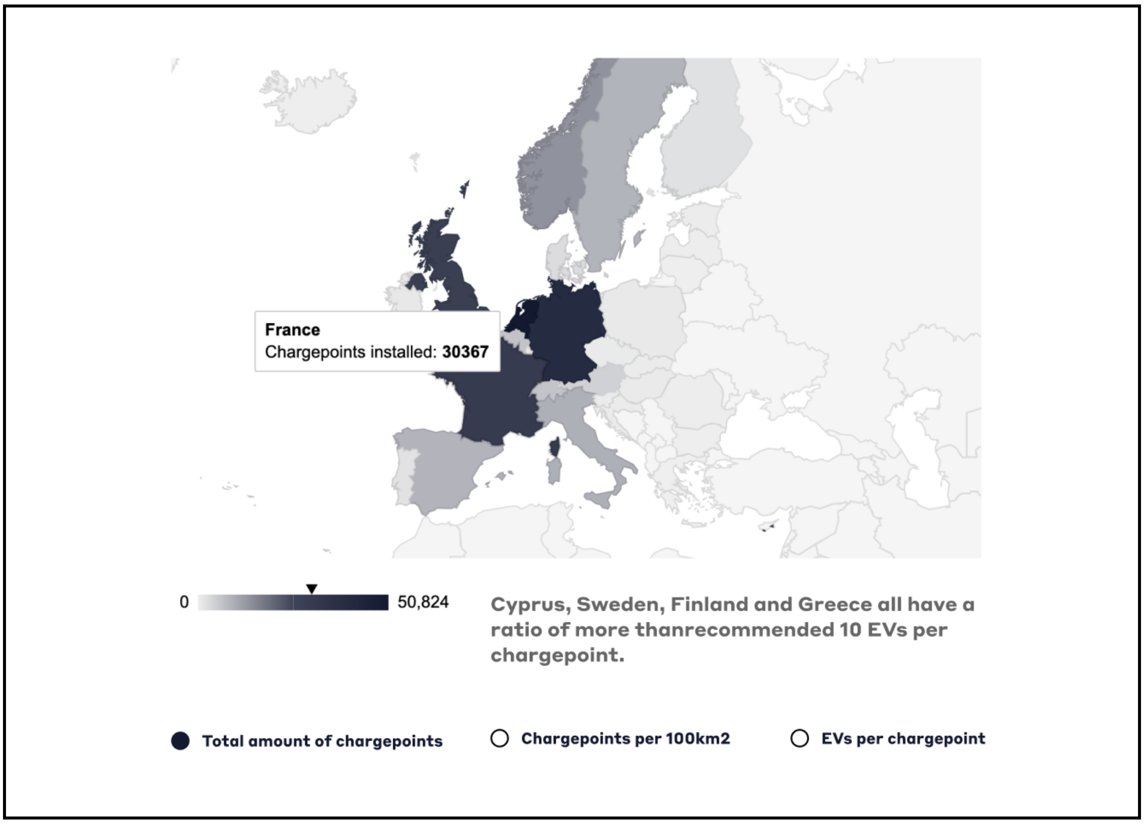


Figure 28 Visualization of the chargepoint distribution among Europe, depending on three factors

4.1.2.3 Testing and results

The general test results of the public survey have been very positive. The key message is successfully transmitted, and the visualization seems aesthetically pleasing and interesting. Some test results are listed in table 4 below.

Topic regarding the question	Average answer from 17 surveys
Text and numbers are clearly visible	4.4
Easy to understand	4.5
Clear purpose	4.6
Aesthetically pleasing	4.6
The visualization is interesting	4.6
Key insight matches the understanding	4.5

Table 4 Results of the general public survey for Visualization 2

During the responsiveness testing, two out of five people had difficulties interacting with the visualization as the countries become very small when displayed on a vertical mobile screen.

4.1.2.4 Design Refinements

While the desktop version was kept as it was, the interaction of the mobile counterpart was reduced to a minimum letting the user only choose between the three different visualizations instead of also providing the exact information per country on hover. As requested by four out of five testers, a larger magnification was also used for the mobile version for both the map as well as the legend.

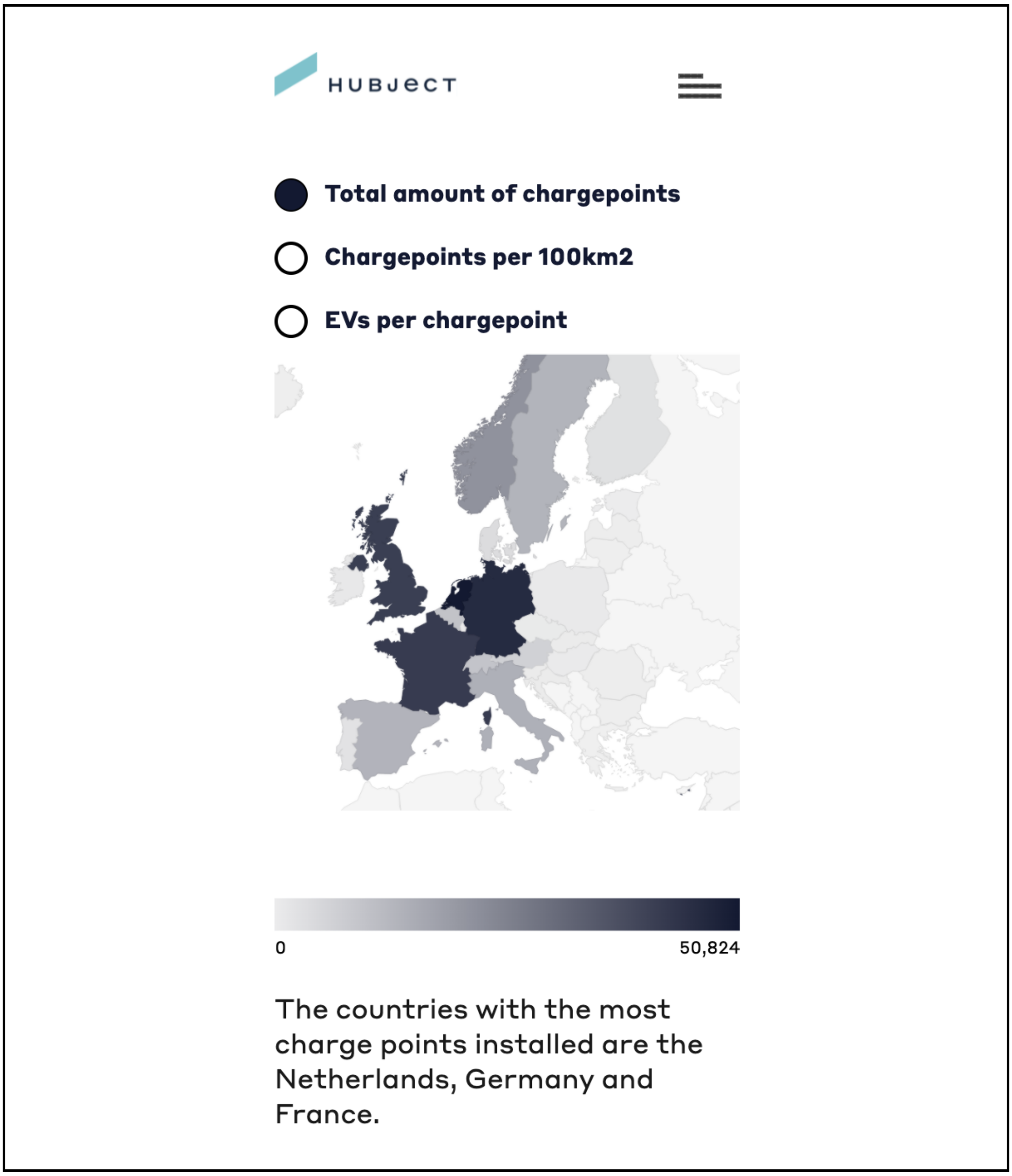


Figure 29 Updated mobile visualization of the charge point distribution among Europe, depending on three factors

4.2 Charging speed of EVs

As already discussed in the state of the art 2.2, several research papers [1] [4] [8] address the possible problem of grid overload due to the rising demand of electricity but efficient solutions have already been found. An optimized strategy for EV charging and discharging based on the peak power was identified by Verzijlbergh et al [58].

To avoid battery drain out, the user gets informed regularly about the battery performance estimation, which is analysed through the SOC (State of charge) technology [59].Vehicle to vehicle (V2V), Vehicle to infrastructure (V2I) as well as Vehicle to grid (V2G) communication and vice versa will be the focus of future transportation systems [60]. For scheduled power management, two-way communication between the user and charging station is used. To best utilize the advantages of the charging process, research has been conducted to forecast EV vehicle battery power management [61] [62]. In order to include those concepts in the dynamic charge scheduling management facilities based on the SOC as well as the vehicle location, the vehicle and charging station have to communicate with each other. This way, slots can be reserved according to the availability and cost functions [63].

4.2.1 Definition of the key insight

For Emobility to be accepted by consumers, EVs must charge within a short span of time. To maintain the grid flexibility, the different available charging systems receive power either from the grid or from high penetration renewable energy sources which are integrated into the charging system [64].

The charging speed depends on two factors: The Voltage, expressed in Volt and the current, expressed in Ampere (A). The energy transfer is based on the Voltage multiplied by the current. There are three sequential phases when charging a Li-ion battery. During the first phase, the "pre-charge" phase, the current is kept low with steadily increasing Voltage. During the second phase, the current remains constant on a high level until the lithium cells have reached a specific Voltage level. In the last phase, the Voltage is kept constant while the current is exponentially decaying. Most of the charging takes place in the second and third phase, which is illustrated in figure 30 below.[65]

To keep the capacity loss of the battery low, it is recommended to always keep a charge between 20 and 80%. The battery degradation varies among the models and depends on external conditions such as climate and charging type but under ideal climate and charging conditions, the average loss is around just 1.6% [66].

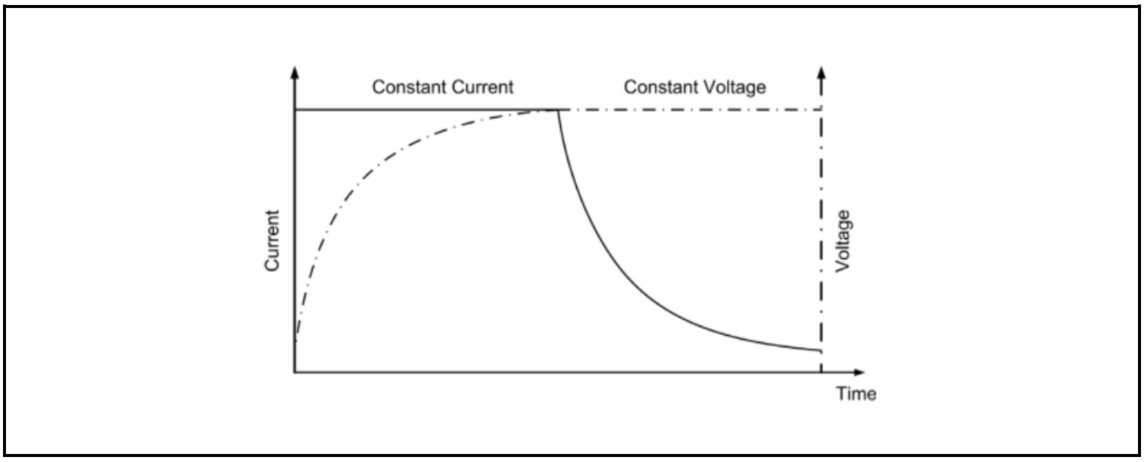


Figure 30 The charging profile of a Lithium-ion battery

The charging speed is one of the key factors of the infrastructure and highly affects the acceptance of electric vehicles. Even when charged on the same socket, the charging time varies among the EV models. The Citroen C-Zero for example has an hourly charge speed of only 20km range while the Renault Zoe ZE40 R110 charges 110km in the same amount of time and from the same type of socket (Type 2 Charger) [67]. As this fact has not been visualized in any form yet, the strong fluctuance of charge time among electric vehicles was chosen to be the key insight regarding this topic. The data has been taken from the EV database [67], which lists the charging speed for different charging scenarios for all EVs on the market.

4.2.2 Choice of Design

For each range bracket, one EV was chosen to be included in the visualization: For <200km range, the Citroen C-Zero, for 200-300km the Opel Corsa E, for 300-400km the Renault Zoe and for a 400-500km range the Tesla Model S.

Two types of charge scenarios are visualised: Type 2 charging and fast charging. The filling of the respective rectangles shows the average amount of charge in km per hour. A vertical stroke is positioned on the corresponding position for the maximum battery capacity. By structuring the visualization like a table, one can easily compare both the differences in charging speed among the individual EVs as well as the difference for the two scenarios per EV.

To emphasize the charging process, the fill which represents the gained range per hour has been animated - similar to a loading bar. As the charge time is just an estimation and it depends on many factors such as battery lifetime, battery temperature, temperature of the environment etc, this will be noted on the bottom of the visualization.

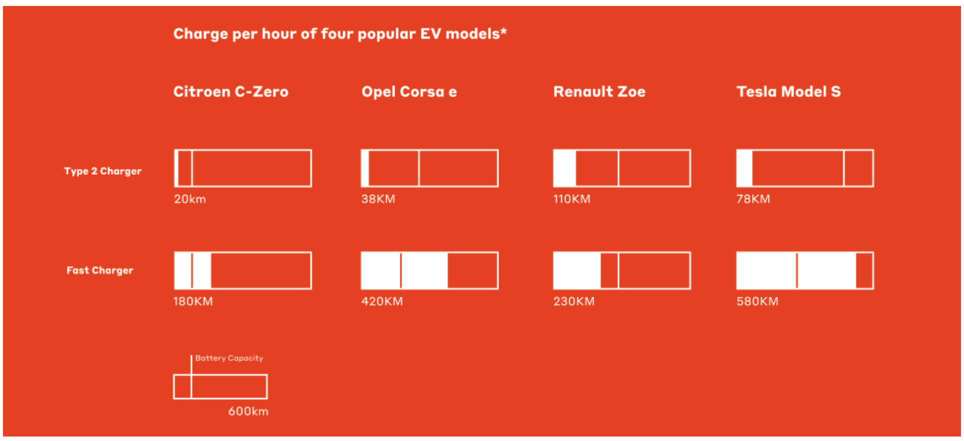


Figure 31 Average charge per hour of four popular EV models

4.2.3 Testing and results

Several flaws have been detected while testing. The battery capacity of the Opel Corsa e as well as the Tesla Model S have not been displayed correctly as two different values have been used for the different charge scenarios. Also, there seemed to be a calculation error for the charge gained per hour. All values have therefore been re-calculated.

When looking at the results of the survey, people had problems to quickly understand the visualization itself. During the responsiveness usability test, no problems have been detected in regard to the visibility of text and numbers. Even though the text becomes a lot smaller, all five participants gave correct answers to the questions. Only the text which says “Battery capacity” in the legend has been pointed out to be hard to read but all participants managed to zoom in and clearly read it.

Topic regarding the question	Average answer from 17 surveys
Text and numbers are clearly visible	4.1
Easy to understand	3.5
Clear purpose	4.1
Aesthetically pleasing	4.1
The visualization is interesting	4.1
Key insight matches the understanding	4.1

Table 5 Results of the general public survey for Visualization 3

4.2.4 Design Refinements

To make the “charging” process clearer, the visualization has been redesigned. Instead of having just minimalistic blocks, a more battery-like shape has been used to display the capacity. The size has been adapted to its respective maximum capacity. The legend has also been updated and the values have now been animated in a counter style to go in line with the charging visualization.

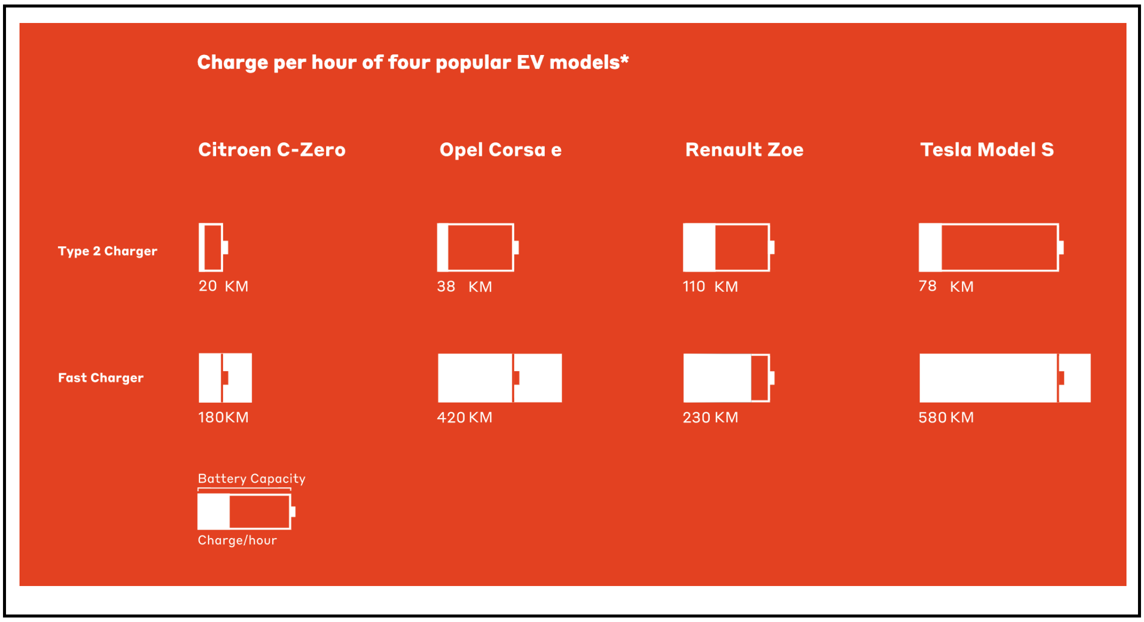


Figure 32 Updated visualization of the average charge per hour of four popular EV models

4.3 Range of EVs

4.3.1 Definition of the key insight

For a functioning charging network across the world and the success of Emobility, it is important to understand the general mindset of vehicle users. Range anxiety is still one of the main concerns which let people hesitate from switching to an EV [34,35,36]. As the range differs significantly among the different EV models, it is important to compare as many cars possible, to get a general understanding of the current limitations in regard to the range.

To connect the market and consumer perception sections with the range, the relationship between the purchase price of an EV and the corresponding range should also be visualized. According to Hidrue et al. (2011) [69], purchase price is one of the main concerns leading to purchase of EVs. But as the production cost of a battery keeps dropping [68], EVs are also becoming more and more available to the public. EVs with an expected real range of up to 460km range can already be purchased for less than €50.000 (German Market Price).

4.3.2 Choice of design

It was decided to compare the range of all currently as available listed EVs with the median range of a gasoline car, as this can be seen as the turning point in regard to the total acceptance of EVs. The data was again taken from the EV database [67].

As the expected range depends on several factors such as the speed, the way of driving, weather- and road conditions, the “real range” instead of the from the automobile manufacturers advertised maximum range has been used for the data set. The length of an orange stroke represents the range of an EV model. While the user scrolls, the strokes will continuously expand following the mouse movement until they reach their respective value. Several vertical lines cross the strokes every 200km so that the user can quickly get an understanding of how many EVs are sharing a certain range bracket.

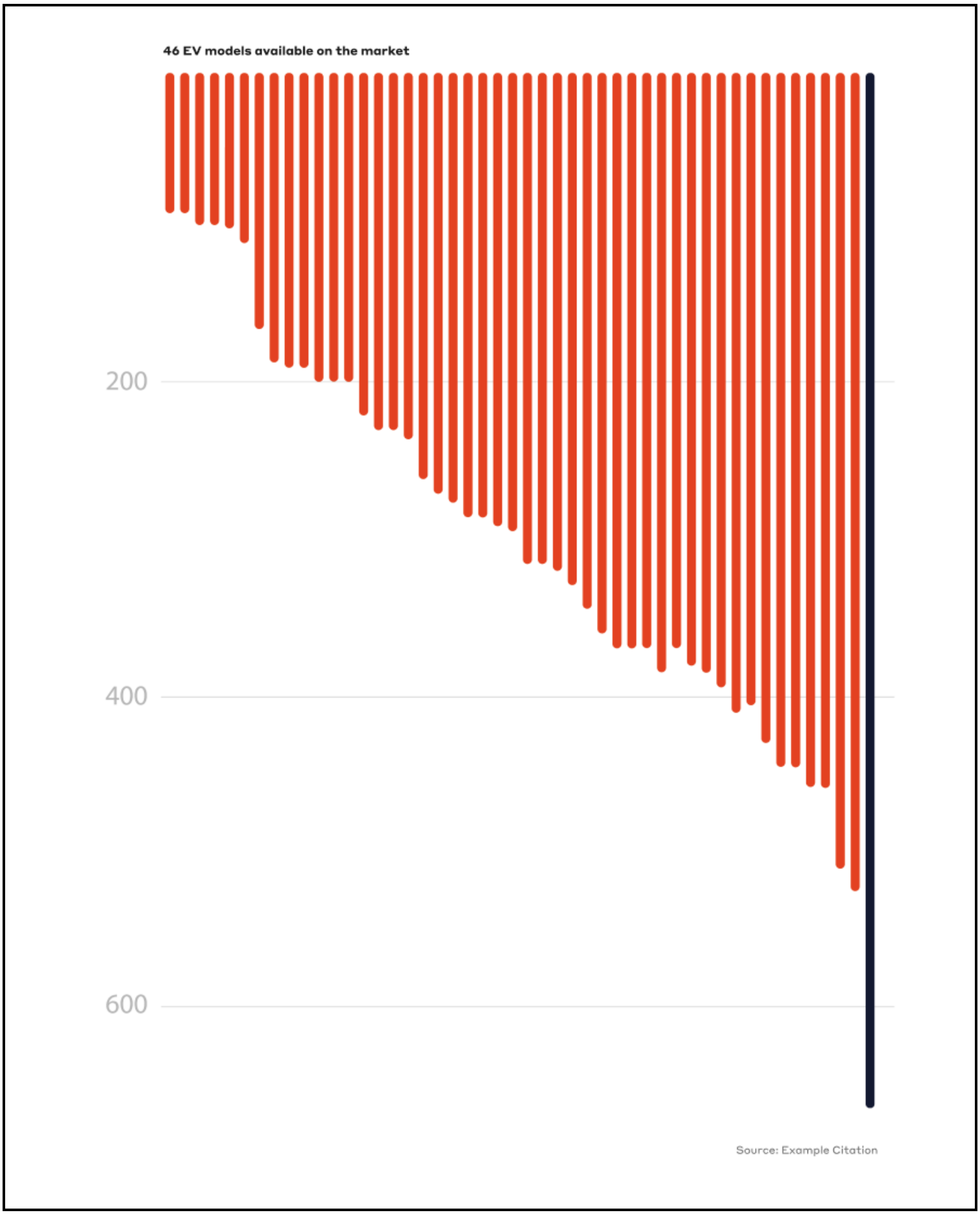


Figure 33 Range of 46 EV models available on the market and median range of a gasoline car

To visualize the relationship between the purchase price of an EV and the range, a heatmap style diagram has been created (Figure 34). Each tile represents the number of cars that are available to purchase within the range and price bracket. Looking at the visualization, several patterns give conclusions about the relationship between range and price:

1. The higher the price, the higher the range. The tiles follow a diagonal pattern, which indicates a clear relationship between price and range.
2. The most EV models are available in the price range between 30.000- and 40.000€- this corresponds to a range between 100 and 400km. This concentration is recognisable through a horizontal pattern of tiles with high contrast
3. Most cars of a single bracket can be found with a purchase price of less than 30.000€ and a range between 200-300km. This can be seen by the tile with the highest contrast.

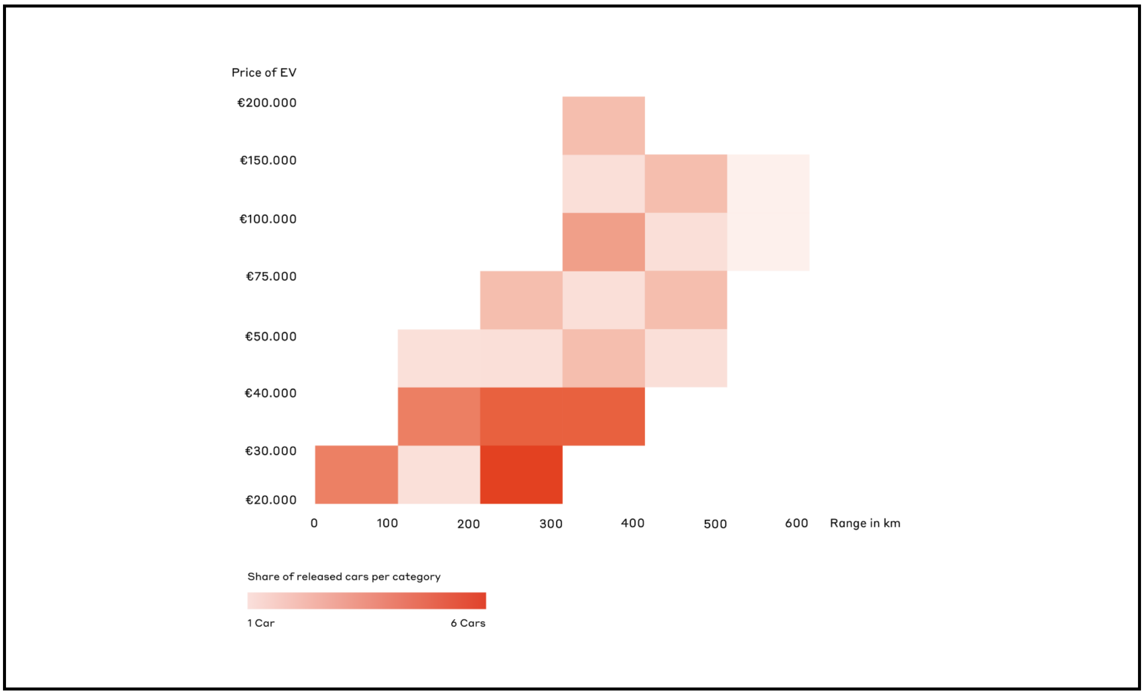


Figure 34 Visualization of the correlation between the purchase price for EVs and the respective driving range in km

4.3.3 Testing and results

The visualization regarding the range of EVs got overall a satisfying rating. Also, in the responsiveness usability testing no problems with the interaction or readability were detected. One remark was to list the values from lowest to highest. Following this structure makes sense as it makes it easier for the viewer to interpret the visualization.

For the Range vs Price Visualization, the low rating for the understanding of the key insight can be derived from the poor formulation of the question in the user test: "*There is a clear correlation between price and range. But up to a 500km range, models can be found with a purchase price of less than €50.000.*" This is just one part of the interpretation of the visualization as explained in the choice of design above and therefore, the user tester might have interpreted it differently. This question has been adapted for the responsiveness test and resulted in a much clearer understanding of the visualization. Regarding readability and interpretation, no errors have been detected on mobile devices.

Topic regarding the question	Answer Range	Answer Range vs Price
Text and numbers are clearly visible	4.6	4.6
Easy to understand	4.2	3.9
Clear purpose	4.3	4.2
Aesthetically pleasing	4.5	4.5
The visualization is interesting	4.3	4.5
Key insight matches the understanding	4.2	3.5

Table 6 Results of the general public survey for Visualization 4 & 5

4.3.4 Design Refinements

For the range visualization, some small changes have been made. Firstly, the description of the y axis has been added, clarifying that the numbers refer to the real range in km on full charge. As explained in 4.1.2.2 above, several values for the range are published by the respective car manufacturers and therefore it is important to mention which one has been used. Secondly, all values have been ordered from lowest to highest value.

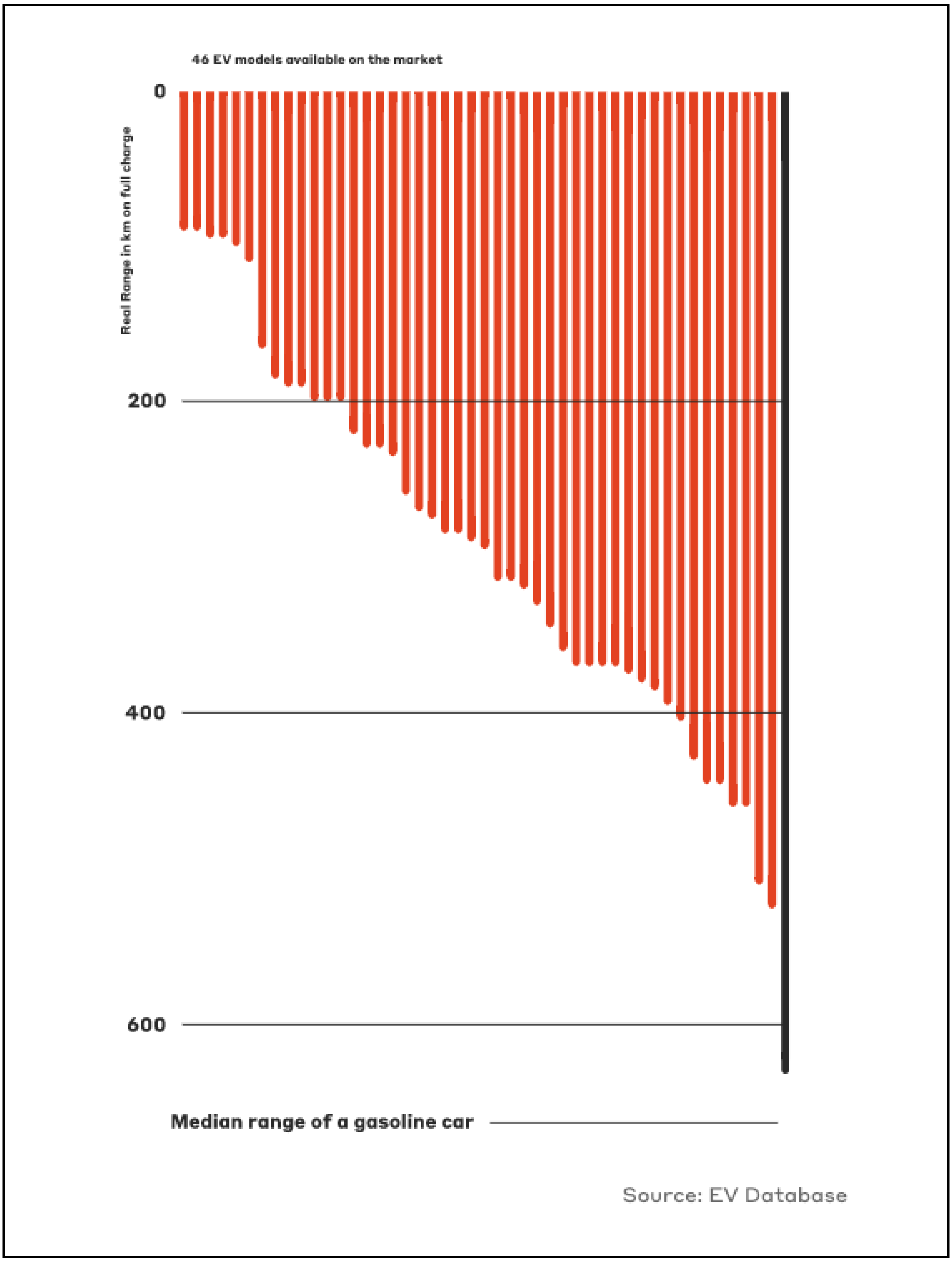


Figure 35 Updated Visualization of the correlation between the purchase price for EVs and the respective driving range in km

For the range vs price visualization, no specific changes have been made. Instead, the formulation of the question regarding the understanding of the key insight has been adapted for the expert test to the following: *“Are you able to draw the following conclusions from looking at the visualization? There is a clear correlation between price and range. The most EV models are available in the price range between 30.000- and 40.000€- this corresponds to a range between 100 and 400km. Most car models can be found with a purchase price of less than 30.000€ and a range between 200-300km.”* The participants of the test can provide their answer on a five-point Likert scale.

4.4 Testing and results for the Landing page

The landing page was also tested on the basis of several factors regarding design, user interaction and the general understanding of the content. Among all results, the story flow had the lowest rating.

Topic	Average answer from 17 surveys
The navigation is intuitive	4.0
The web design stays coherent	4.5
The story flow is concise and logic	3.9
The web experience is pleasing	4.5
Gain of better understanding of Emobility after viewing the website	4.3

Table 7 Results of the general public survey for the landing page

To see if the low rating occurs from the connection of the different sections or the content itself, it was also analysed if the insight and facts sections provide useful information to understand the purpose of the visualization. The results are listed according to their respective sections in table 8 below.

Visualization	Insight and facts provide useful information
Charging network around the world	3.8
Charging in the EU	4.5
Charge Time	4.1
Range	4.1
Range vs Price	4.1

Table 8 Results if the information provided additional to the visualizations have been useful

With an average of 4.1 and only one value below a rating of 4, the issue seems to be the general story flow. The copy of the website was therefore adjusted. A feedback which has been received several times is that the users had some lack of knowledge of the specific term "EV" (Electric Vehicle). The introduction was therefore adapted to include and explain this keyword. Besides that, key factors that influence Emobility as well as a future outlook regarding those factors were implemented to frame the story and provide additional information.

4.5 Expert test and results

After the above-mentioned changes have been made and the visualizations have been updated according to the feedback, the expert test has been executed. In total, six CEOs and Marketing directors of companies within the industry have given feedback by filling out the survey. The most important results are listed in table 10 below. For the visualization related questions, the average answer among all five visualizations has been taken. Overall, the feedback has been very positive with just a few ratings below a 4 for some individual questions of certain visualizations. As the main purpose of the test was finding out if the visualizations provide interesting insights for experts of the fields as well, judging on the high ratings it can be concluded that the goal has been reached.

Topic	Average answer
Website related	**4.3**
The website navigation is intuitive	4.2
The design stays coherent throughout the website	4.2
The storyflow is logical and concise	4.0
The website experience is pleasing	4.3
After visiting the website, I have a better understanding of Emobility	4.5
Visualisation related	**4.3**
All text and numbers are clearly visible	4.2
The visualization is easy to understand	4.2
The purpose of the visualization is clear	4.3
The visualization is aesthetically pleasing	4.3
The visualization is interesting	4.4
Insights and Facts provide useful information	4.1
Key insight matches the interpretation	4.4

Table 9 Results of the expert test

4.6 Client Feedback

When presenting the work in progress to Christian Hahn, CEO of Hubject, the visualizations as well as the general content have been approved and deemed favourable. But in regard to the marketing effect of the project, several possible improvements have been pointed out.

Instead of having just one link to Hubject's website, it was decided to implement a navigation bar on top of the page with several links to the respective sections of the Hubject website. This way, customers can directly be forwarded to the topic they are interested in. Besides that, downloadable assets have been prepared to be shared on social media. A call to action to download them will be implemented below each visualization as well as on the bottom of the page (see Figure 35 below). Additionally, a printable version of the Website in PDF format will be offered to download as well. The option of collecting visitor's data such as name and Email address when requesting the downloadable assets still needs to be discussed.

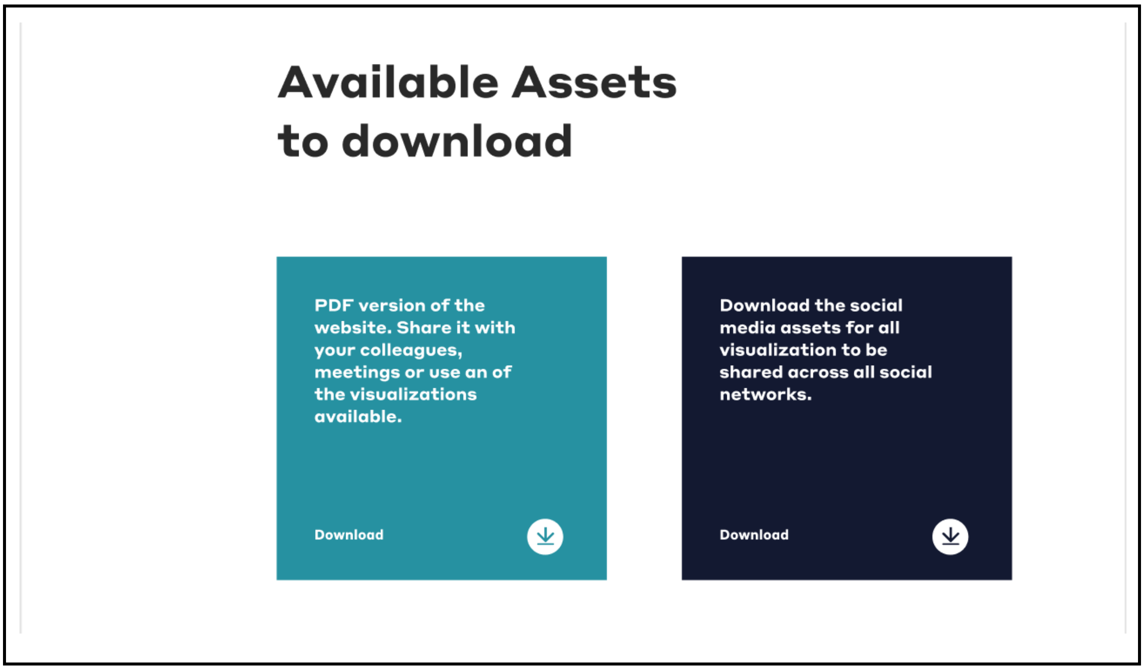


Figure 36 Download buttons which have been added at the end of the landing page

4.7 Analytic Tools

Google Analytics and Hotjar could not be set up as the client has not provided the details for connecting the website with the domain before the submission of this project report. Those tracking tools will be implemented as soon as the website goes live, a definite conclusion of the success of the project can therefore not be drawn at the moment.

5 Conclusion and Recommendations

5.1 Conclusion

In order to fully answer the research question, the characteristics of the current state of Emobility infrastructure have been explored (SQ1) through literature research. Challenges as well as political motivators have been pointed out (SQ2 & SQ3) and laid the foundation for the story of the landing page, which has been chosen to be the format to present the current state of Emobility. In the state-of-the-art section, data visualizations which are already available in the field have been explored and analysed (SQ5) and with this knowledge in mind, new types of visualizations have been designed based on the predefined key insights. The key insights have been formulated in such a way that they contribute to answering the main research question as well as address topics that have not been visualized yet (SQ4&6). After the converging design phase, interactivity as well as animation options have been explored to create a more pleasant user experience and the visualizations have been developed in such a way that they could be implemented into the website. They have then been tested both from the general public as well as from experts of the field to make sure that the content is valuable and interesting for both target groups (SQ7).

Looking at the results of the testing, it can be concluded that the project has been very well received and together with the project of Gleb Podorozhnyy, a comprehensive overview of the current state of Emobility has been presented, which will ultimately contribute Hubject's image as a thought leader of Emobility.

Further testing with analytic tools as mentioned in 3.2.5 is needed to conclude how successful the project has been in regard to the marketing intentions of Hubject. This is the only requirement from the client side where no final conclusion can be drawn as the website has not been launched publicly yet. The website will be launched under the domain www.insight.hubject.com. A screenshot of all the sections of the final webpage can be seen in the figure 37 below. This includes both the topics covered in this report and the topics of Gleb Podorozhny´s Project. The content might still change as it will be adapted to the feedback which will be gained from the evaluation of the analytic tests.

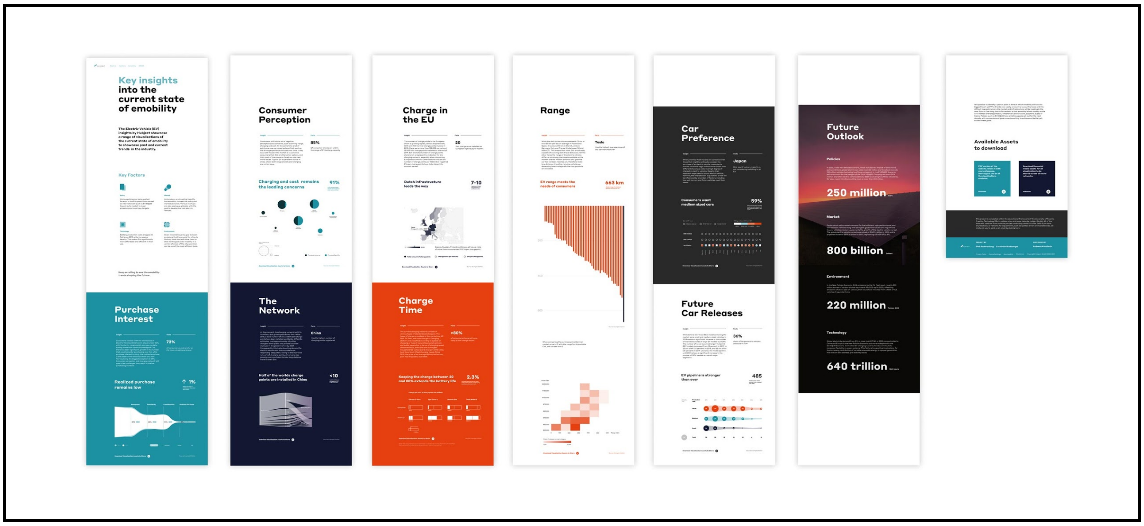


Figure 37 Screenshot of the entire landing page including the sections of Gleb Podorozhnyy

5.2 Recommendation

For Hubject to be able to keep the image as a thought leader of Emobility it is crucial to always be ahead of the competition. In regard to this project this means to ensure that the data sets with their respective visualizations and content should constantly be updated. Most of the visualizations have been developed in such a way that this can be done with just updating the data sets externally instead of having to redesign and reimplement them. Other or new topics which might evolve from the development of Emobility should be included and added if applicable as well.

5.3. Future Research

One topic that has not been visualized and has only been mentioned in the facts and general content section of the final project is the context of renewable energy. As mentioned several times throughout the report, the goal of reducing CO2 emissions is one of the main driving factors of Emobility [5] [6] [9]. Possible topics that could be discussed and visualized are:

1. How is the rise of Emobility contributing to offsetting CO2 emissions worldwide?
2. What is the percentage of renewable energy used to charge EVs?
3. How much CO2 is emitted during the production of an EV compared to a gasoline car?
4. How much CO2 is emitted for a charge of 100km depending on the energy mix of certain countries? What is the equivalent for a gasoline or diesel car when driving this range?
5. How is the share of renewable energy sources changing and how is it expected to change?
6. How will the batteries be recycled?

As this is such an extensive topic on its own it was decided to just mention the key factors within the story. After implementing the respective content, the need to include more information or visualizations in regard to the topic has not been mentioned by the user testers anymore. Nevertheless, the impact of Emobility on reducing CO2 emission world-wide could be used as a topic for a similar project in the future.

Another subject that has been discussed only briefly in the project is the impact of political actions such as subsidies for purchasing EVs and tax reductions as well as fines for automakers when failing to reach the CO2 target. As the regulations differ a lot among the different countries it is challenging to compare them and draw conclusions regarding the success of a certain policy. Amongst other things, because the acceptance of E Mobility depends on a lot of other factors as well, such as the openness to innovation and the purchasing power of the population of a country.

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Appendices

Appendix 1

Sankey Diagram Code

HTML

```
<script type="text/javascript" src="https://www.gstatic.com/charts/loader.js"></script>
    <div id="sankey_basic" style="width: 600px; height: 400px;"></div>
```

CSS

```
body {
   background-color: #131832;
}
```

JavaScript

```
  google.charts.load('current', {'packages':['sankey']});
   google.charts.setOnLoadCallback(drawChart);

   function drawChart() {

     var data = new google.visualization.DataTable();
```

```
        data.addColumn('string', 'From');
        data.addColumn('string', 'To');
        data.addColumn('number', 'Installed');
        data.addRows([
          [ 'Public Chargers', 'China',275000],
          [ 'Public Chargers', 'U.S.A.',54500],
          [ 'Public Chargers', 'Japan',29971],
          [ 'Public Chargers', 'E.U.',118584],
          [ 'Public Chargers', 'Korea',9304],
          [ 'Public Chargers', 'Canada',7940],
          [ 'Public Chargers', 'Others',30885],
          [ 'China', 'Slow Chargers',163667],
          [ 'China', 'Fast Chargers',111333],
          [ 'U.S.A.', 'Slow Chargers',50258],
          [ 'U.S.A.', 'Fast Chargers',4242],
          [ 'Japan', 'Slow Chargers',22287],
          [ 'Japan', 'Fast Chargers',7684],
          [ 'E.U.', 'Slow Chargers',107446],
          [ 'E.U.', 'Fast Chargers',11138],
          [ 'Korea', 'Slow Chargers',5394],
          [ 'Korea', 'Fast Chargers',3910],
          [ 'Canada', 'Slow Chargers',7100],
          [ 'Canada', 'Fast Chargers',840],
          [ 'Others', 'Slow Chargers',25934],
          [ 'Others', 'Fast Chargers',4951],
        ]);

        // Sets chart options.
        var options = {
         'width': 630,
            'height': 400,
        };
    var colors = ['#FFFFFF', '#ECECEC', '#DDDDDD', '#D4D4D4',
                 '#cab2d6', '#ffff99', '#1f78b4', '#33a02c'];

var options = {
    textStyle: {
```

```
      color: '#ffff99'
    },
      backgroundColor: 'transparent'
    };

    var options = {

      sankey: {
        node: {label: { fontName: 'Times New Roman',
                        fontSize: 12,
                        color: '#FFFFFF',
                      },
          colors: colors
        },
        link: {
          colorMode: 'gradient',
          colors: colors
        }
      }
    };



        // Instantiates and draws the chart, passing in some options.
        var chart = new
google.visualization.Sankey(document.getElementById('sankey_basic'));
        chart.draw(data, options);
      }
```

Updated HTML Code

```
google.charts.load('current', {'packages':['sankey']});
      google.charts.setOnLoadCallback(drawChart);

      function drawChart() {

        var data = new google.visualization.DataTable();
        data.addColumn('string', 'From');
```

```
        data.addColumn('string', 'To');
        data.addColumn('number', 'Installed');
        data.addRows([
          [ 'Public Chargers', 'China',275000],
          [ 'Public Chargers', 'U.S.A.',54500],
          [ 'Public Chargers', 'Japan',29971],
          [ 'Public Chargers', 'E.U.',118584],
          [ 'Public Chargers', 'Korea',9304],
          [ 'Public Chargers', 'Canada',7940],
          [ 'Public Chargers', 'Others',30885],
          [ 'China', 'Slow Chargers',163667],
          [ 'China', 'Fast Chargers',111333],
          [ 'U.S.A.', 'Slow Chargers',50258],
          [ 'U.S.A.', 'Fast Chargers',4242],
          [ 'Japan', 'Slow Chargers',22287],
          [ 'Japan', 'Fast Chargers',7684],
          [ 'E.U.', 'Slow Chargers',107446],
          [ 'E.U.', 'Fast Chargers',11138],
          [ 'Korea', 'Slow Chargers',5394],
          [ 'Korea', 'Fast Chargers',3910],
          [ 'Canada', 'Slow Chargers',7100],
          [ 'Canada', 'Fast Chargers',840],
          [ 'Others', 'Slow Chargers',25934],
          [ 'Others', 'Fast Chargers',4951],
        ]);

        // Sets chart options.
        var options = {
         'width': 630,
            'height': 400,
        };
    var colors = ['#FFFFFF', '#ECECEC', '#DDDDDD', '#D4D4D4',
                  '#cab2d6', '#ffff99', '#1f78b4', '#33a02c'];

var options = {
    textStyle: {
        color: '#ffff99'
```

```
  },
    backgroundColor: 'transparent'
  };

  var options = {

    sankey: {
      node: {label: { fontName: 'Styrene A',
                     fontSize: 14,
                     color: '#FFFFFF',
      },
      link: {
        colorMode: 'gradient',
        colors: colors
      }
    }
  };



    // Instantiates and draws the chart, passing in some options.
    var chart = new
google.visualization.Sankey(document.getElementById('sankey_basic'));
    chart.draw(data, options);
  }
```

Appendix 2

User test section 1

Hubject Data Visualization User Testing

The goal of this test is to determine perception and understanding of visualizations that have been created for Hubject GmbH as part of a thesis by Gleb Podorozhnyy and Corbinian Buchberger. You will need 10-15 minutes to complete the evaluation. Your contribution to this project is greatly appreciated!

In this survey you will be asked to evaluate 9 data visualizations and your understanding and perception of them. All visualizations are related to the topic of electric mobility, with a focus on the market and existing infrastructure, such as range and charging. All information collected in this form will be used only to evaluate the understanding of the visualizations in this research. In addition the results may be published within the bachelor thesis of both students mentioned. The data gathered is fully anonymous, no personal details will be collected through the form or any tracking and marketing software.

If you are further interested in the research, please contact by email g.podorozhnyy@student.utwente.nl.

Thank you for your participation and feedback.

I accept my participation and that my data in response to this evaluation will be gathered anonymously *

- Yes
- No

Age (optional)

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and over

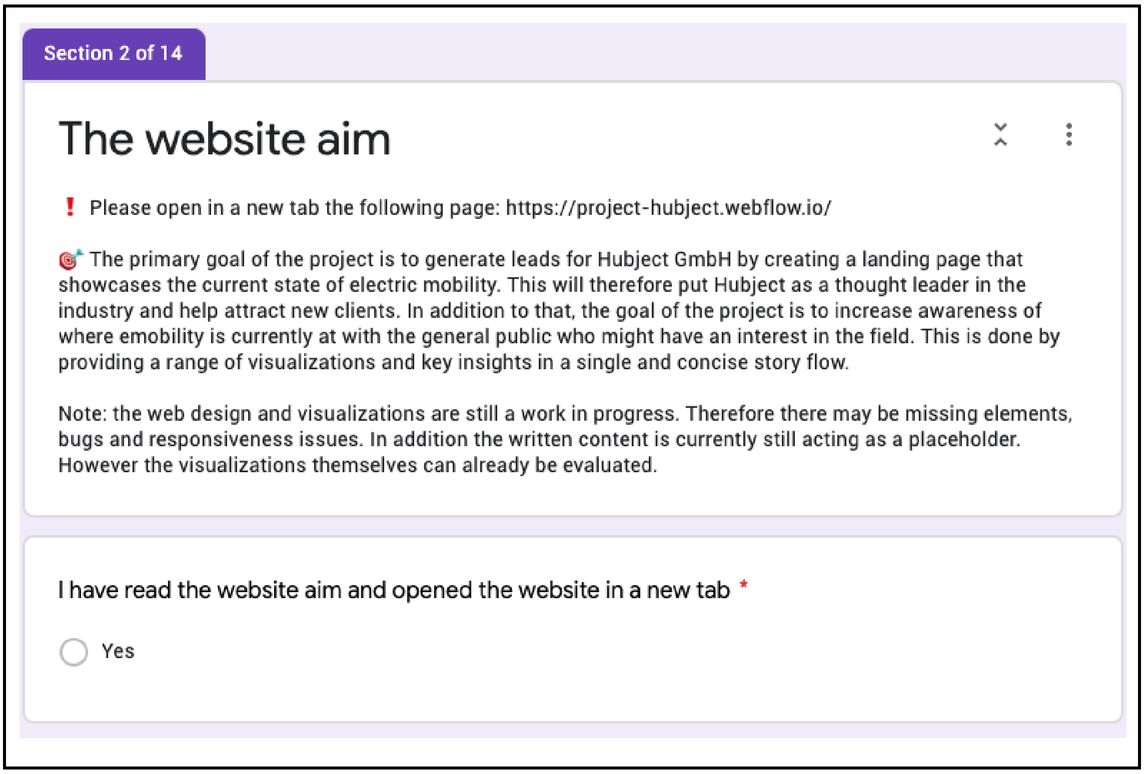
Are you a student? *

- Yes
- No

If you are a student what is your study?

Short answer text

User test section 2



Section 2 of 14

The website aim

❗ Please open in a new tab the following page: https://project-hubject.webflow.io/

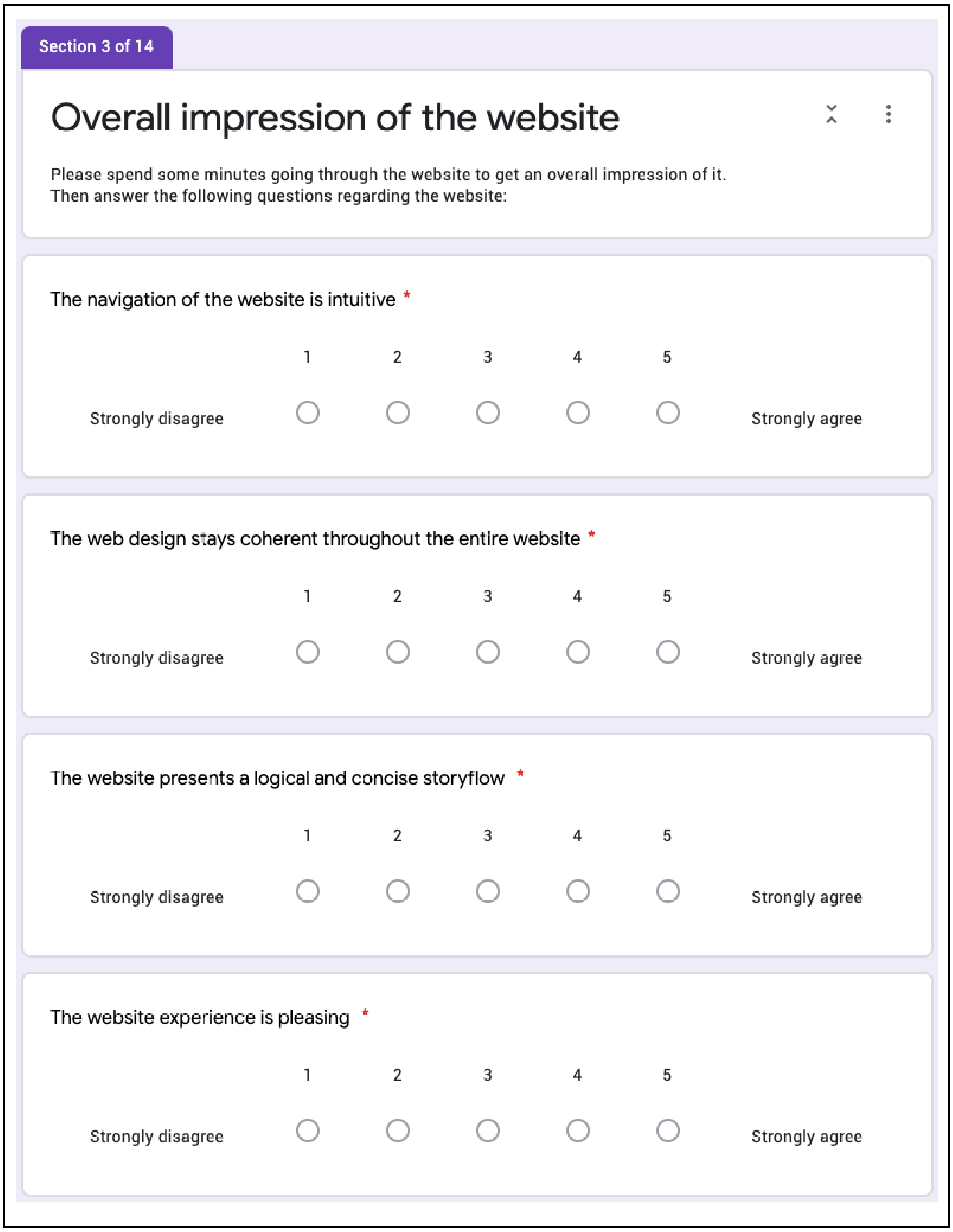
🎯 The primary goal of the project is to generate leads for Hubject GmbH by creating a landing page that showcases the current state of electric mobility. This will therefore put Hubject as a thought leader in the industry and help attract new clients. In addition to that, the goal of the project is to increase awareness of where emobility is currently at with the general public who might have an interest in the field. This is done by providing a range of visualizations and key insights in a single and concise story flow.

Note: the web design and visualizations are still a work in progress. Therefore there may be missing elements, bugs and responsiveness issues. In addition the written content is currently still acting as a placeholder. However the visualizations themselves can already be evaluated.

I have read the website aim and opened the website in a new tab *

Yes

User test section 3



Section 3 of 14

Overall impression of the website

Please spend some minutes going through the website to get an overall impression of it.
Then answer the following questions regarding the website:

The navigation of the website is intuitive *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The web design stays coherent throughout the entire website *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The website presents a logical and concise storyflow *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The website experience is pleasing *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

User test section 4

This section was repeated for each visualization

I can clearly see all the information including text and *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The visualization is easy to *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The purpose of the visualization is *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The visualization is aesthetically *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The visualization is *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The Insight and Facts sections provide useful information to understand the purpose of the visualization *

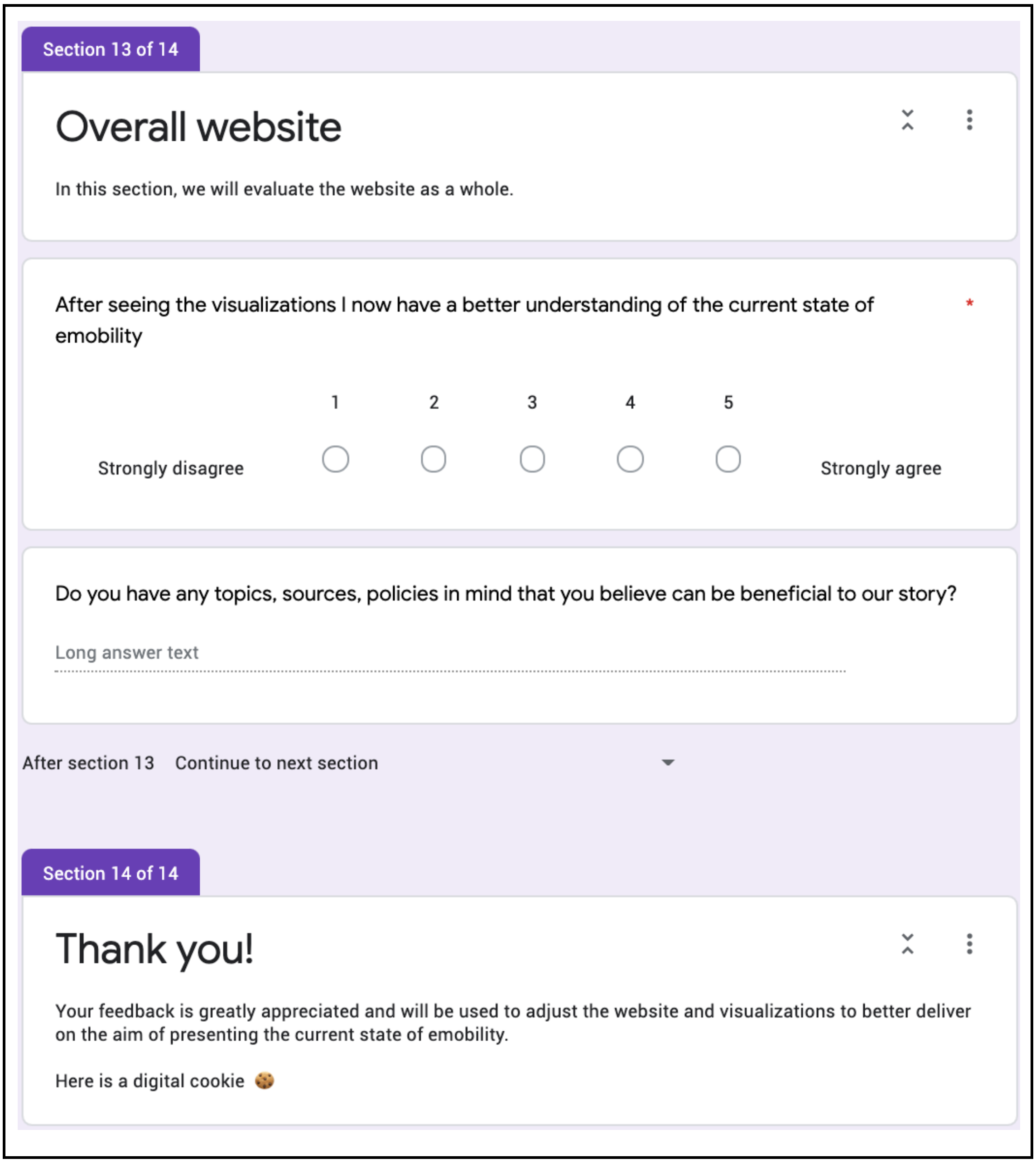
	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Is your understanding of the visualization the following? While interest in EVs is high, purchasing remains low. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Is there anything misleading in the *

User test section 13&14



Section 13 of 14

Overall website

In this section, we will evaluate the website as a whole.

After seeing the visualizations I now have a better understanding of the current state of emobility *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Do you have any topics, sources, policies in mind that you believe can be beneficial to our story?

Long answer text

After section 13 Continue to next section

Section 14 of 14

Thank you!

Your feedback is greatly appreciated and will be used to adjust the website and visualizations to better deliver on the aim of presenting the current state of emobility.

Here is a digital cookie 🍪

Glossary

Term	Abbreviation	Explanation
Electromobility mobility/ Electric mobility	Emobility	Electromobility is a highly networked branch of industry that focuses on meeting mobility needs under sustainability aspects, using vehicles that carry an energy storage system and use an electric drive that can vary in the degree of electrification.
Electric Vehicle	EV	A vehicle propelled solely or in part by an electric motor powered by batteries that can be recharged from a source outside the vehicle. (Includes both all-electric vehicles and plugin hybrids.)
All-electric vehicle / battery electric vehicle	AEV/BEV	A vehicle propelled solely by an electric motor powered by batteries that can be recharged from a source outside the vehicle.
Plug-in hybrid	PHEV	A vehicle propelled in part by an internal combustion engine and in part by an electric motor powered by batteries that can be recharged from a source outside the vehicle. Internal combustion engine ICE An engine that runs on liquid fuels including gasoline or diesel.
New energy vehicle	NEV	A term used in China for vehicles not powered by an internal combustion engine.
Charging point		A piece of equipment for charging an electric vehicle, other than an unmodified wall outlet Charging station
Charging station		A location with multiple charging points/posts.
Level 1 charger	L1	An EV charger using a standard 120-volt outlet.
Level 2 charger	L2	An EV charger using a 240-volt electrical circuit, similar to a dryer or an electric stove top.
DC fast charger	DCFC	A 480-volt charger that can deliver as much as hundreds of kWs of power.
Internal combustion engine vehicle	ICEV	Usually referred to as a gasoline car as it typically uses a spark-ignited internal combustion engine, rather than the compression-ignited systems used in diesel vehicles.

Garmisch-Partenkirchen, 04.07.2020

Place, Time

Signature