

Fast chargers for all: multistandard charger deployment and usage in Europe

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Summary

Equipped with CHAdEMO, Combo2 and AC connectors, multistandard fast chargers have become the de-facto standard in Europe, catering to all fast-chargeable EVs on the market. This paper reviews the general fast charging infrastructure deployment, presents multistandard charger usage data from European projects and demonstrates that the usage of connectors on these chargers is unequal. This is due to influences from multiple factors including the local plug-in market composition, government incentives, infrastructure availability and user behaviours. Stakeholders need to remain alert and adapt to the resulting ever-changing market needs, with support from robust and flexible e-mobility ecosystem including policy and technology.

Keywords: fast charge, CHAdEMO, Combo, EU (European Union), policy

1 Introduction

CHAdEMO is the first fully commercialised DC fast charging technology for mass-marketed electric vehicles (EV) in the world, but its deployment did not follow the same patterns in all parts of the globe.

In the first part of this paper, we shall review the development of global fast charging infrastructure, focusing on the European market, which was the first to arrive at “multistandard” chargers in conjunction with the global and regional standardisation discussions. We will then touch on the proliferation of multistandard chargers in Europe, a phenomenon that has quickly spread out in the last few years.

In the second part of the paper, taking multistandard fast charger usage data from four European countries, we shall present examples of EV markets and their usage of fast charging infrastructure, from which we shall extract learning and implications for the near-future deployment of fast charging infrastructure in terms of operations, legislation support, and technological development.

2 Global DC fast charging infrastructure development and Europe

2.1 CHAdEMO in the world

CHAdEMO was the first DC fast charging protocol for mass produced EVs in the world. Since 2009, many investors and e-mobility stakeholders have helped expand the CHAdEMO fast charging networks. With over 10,000 charge points serving some 240,000 EVs globally at the end of 2015, it remains today the most widely used fast charging protocol in the world, both in terms of number of charge points as well as the number of EVs compatible with the technology.

2.1.1 Global charge point evolution

According to CHAdeMO Association, there are 10,708 publicly accessible charge points installed globally: 5,960 in Japan, 3,028 in Europe, 1,612 in the U.S.A., and 108 in other regions as of March 2016, across 50 countries in five continents [1]. As a comparison, the second largest global network, Tesla, has 3,574 Superchargers (at 609 Supercharger stations) in place [2], followed by CCS Combo2 (in Europe) with 1,779 [3] and SAE Combo 1 with 833 (in the U.S.) [4].

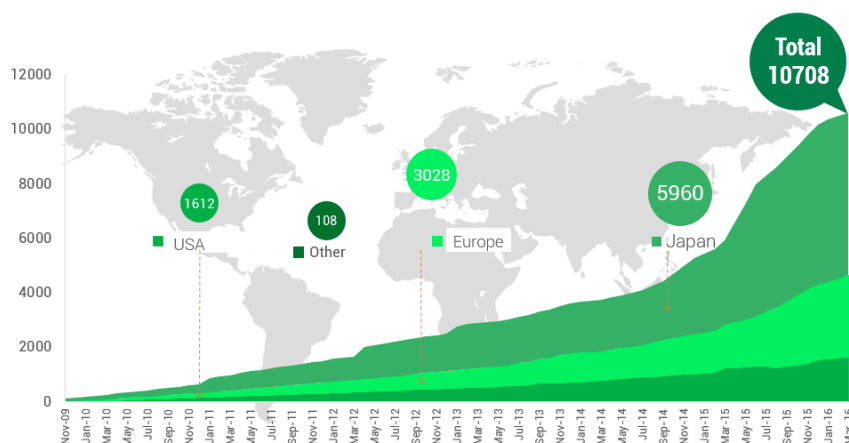


Figure1: CHAdeMO charge point evolution (11/09-03/16)

2.1.2 EV market by fast charging inlet type

With the early start and seven years of in-market experience, CHAdeMO has the largest number of EVs equipped with its DC fast charging inlet. According to IHS Automotive [5], the total number of battery EVs sold from 2010 through 2015 is approximately 720,000, of which close to half are compatible with CHAdeMO (33% equipped with CHAdeMO inlets, 15% via adapter for Tesla). When we exclude those EVs that are not fast-chargeable (up to 22kW and marked “None” in Table1, the majority are Chinese EVs), the percentage goes up to 77%, demonstrating that almost 4 out of 5 fast-chargeable EVs on the roads today are compatible with CHAdeMO.

Table1: EV market share by fast charging inlet type (2010-2015) [5]

	CHAdeMO	Combo1/2	Other	None
Of all BEVs	48%	9%	5%	38%
Of all fast-chargeable EVs	77%	15%	9%	-

2.1.3 Variety of charger/connectors

Since its first products, fast chargers and connectors have evolved over time, increasing in the number of providers along the way as the technology matured. As of March 2016, there are 50 charger manufacturers producing CHAdeMO chargers, offering over 200 certified models in the world [6]. In terms of connectors, if we take the example of the most current version of CHAdeMO protocol (version 1.0), one can find five UL/CE-certified connectors by four manufacturers listed on the Association’s website [7]. The design has also changed quite a lot from the initial connector that required operations with two hands to various one-button types allowing for easy manoeuvre with improved ergonomic design.



Figure2: CHAdeMO connectors for ver 1.0

2.1.4 Standardisation and certification

Starting with the publication of JIS (Japanese Industrial Standards) standard (TS D 0007) in 2012 [8], technical standards organisations of both international and regional levels have recognised CHAdeMO. In 2014, CHAdeMO was published as a DC fast charging standard by IEC (International Electrotechnical Commission) along with two other systems (CCS Combo1/2 and GB/T). In the same year, it was published as an EN standard by CENELEC (European Committee for Electrotechnical Standardization), a European official standards organisation, together with Combo2 (IEC/EN 61851-23 for the charging system, IEC/EN 61851-24 for communication, and IEC/EN 62196-3 for the connector [9] [10]). Most recently, in March 2016, CHAdeMO was published as an IEEE standard with Reference 2030.1.1-2015[11].

As the number of EVs and chargers increase, ensuring compatibility between EVs and chargers becomes crucial. CHAdeMO sets itself apart from the other standardised technologies with its third-party certification process. Consisting of basic circuit requirement, control sequence and communication protocol, CHAdeMO's certification system started in 2010 and remains the only certification system for fast chargers in the world [12]. Initially in-house at CHAdeMO, the tests are now outsourced to and available at five third-party homologation organisations. The list of all certified chargers is made available on the website of CHAdeMO Association in full transparency [6].

2.2 CHAdeMO in Europe

Starting from scratch, CHAdeMO played a crucial role in the roll-out of the first mass produced DC fast-chargeable EVs in Europe, proposing a standardised interface between EV and fast chargers and ensuring interoperability. With the eventual arrival of new technical protocols and integrating them in the form of multistandard chargers, CHAdeMO charging infrastructure is well established and continues to be an indispensable part of EV charging infrastructure in Europe.

2.2.1 The EU Directive

The deployment of CHAdeMO chargers in Europe started towards the end of 2009. CHAdeMO Association Europe was set up in 2010, attracting 50 member companies in Europe within a year. By early 2013, there were over 600 CHAdeMO chargers in 23 European countries servicing 23,000 EVs. International and European standards organisations were in preparation to publish both CHAdeMO and Combo2 as standards, when, on January 24, 2013, the European Commission in its draft directive on the deployment of alternative fuels infrastructure designated Combo2 as the only European DC plug [13].

The rumour of CHAdeMO being phased out of the European market has caused a confusion among the e-mobility stakeholders: there was already one established technology in the market, but EU was pointing at a new protocol with no charger installed nor EV in the market (Combo2-equipped EVs were launched in the market in Q4, 2013) as the European plug. With a great deal of uncertainty over the early adopters of EVs and innovative e-mobility stakeholders, including some EU member state governments that had heavily invested in CHAdeMO, EV charging infrastructure investments were brought to a temporary standstill.

2.2.2 Multistandard chargers: product of market and policy interaction

While the EU institutions wrestled with the wording of DC charging standards and e-mobility investors wondered how this situation could be reconciled, charger manufacturers responded with a solution: multistandard chargers. Capable of charging all fast-chargeable EVs, both existing and coming to the market, irrespective of the type of charging they use, multistandard fast chargers have become an instant hit and eventually a de-facto European standard. Today, 11 manufacturers offer multistandard chargers, and almost 1,500 have been deployed across Europe [14].

Acknowledging the needs of EV drivers and responding to calls for greater technological neutrality, the EU has eventually softened the wording of the directive to '*at least* Combo2' and added a recital endorsing multistandard charging, which says, "Interface to charge electric vehicles could include several socket outlets or vehicle connectors as long as one of them complies with the technical specifications set out in this Directive, so as to allow multistandard recharging" [15].

2.3 Multistandard charger deployment in Europe

2.3.1 Private investors

Since multistandard chargers were a market innovation, it was naturally the private investors who first adopted them. Ecotricity, the first and biggest fast charging network in Britain, already covers hundreds of kilometres with multistandard chargers [16]. Clever, the leading Danish operator, runs a national network of 50+ multistandard chargers (more details in Section 3.3), while Fastned, the Dutch start-up planning to erect 130 multistandard charging stations along the motorway in the Netherlands, has already completed 50 locations (more details in Section 3.2).

2.3.2 EU TEN-T projects

They were quickly joined by EU-funded projects as a clear recognition of the EU's support for these "chargers for all." A handful of multistandard fast charger installation projects in EU's framework of TEN-T (Trans-European Transport Networks) funding scheme with a total investment of over 30 million EUR (50% EU-funded) were commissioned towards the end of 2013. From Ireland and the UK to France, across central Europe and Scandinavia, a total of over 500 multistandard chargers were built across 11 countries [17]. In many of these projects, automakers with EVs of different fast charging options participated together in support of the "charger for all" principle. Successors to these projects, under the CEF (Connecting Europe Facility) grant scheme with 50% EU funding, will add another 530 multistandard chargers across Europe in the coming year [18].

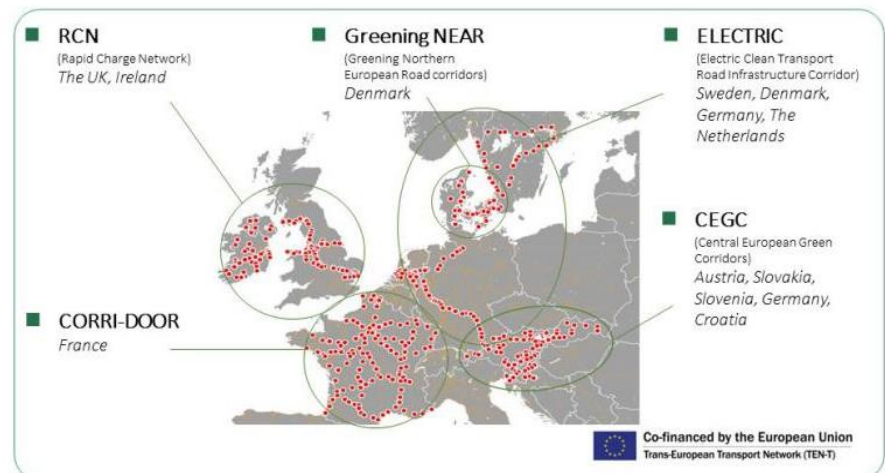


Figure3: EU's TEN-T project examples for fast charging infrastructure (-2013)

3 Multistandard charger usage data

EU private/public sectors aligning on multistandard benefits all stakeholders: above and foremost, EV users can rest assured that the infrastructure their car uses will continue to be developed, irrespective of the standard with which it is compatible. Operators can serve a much greater customer base with minimal additional costs as the incremental cost of adding a connector remains 5-10% of the overall charger and installation costs combined. OEMs can stay with their choice of charging inlets without worrying about the infrastructure.

In this paper, we aimed to see how and by which group of EVs multistandard fast chargers were being used. Comparing the usage of three fast standard connectors in Europe: CCS Combo2 (hereafter CCS), CHAdeMO and AC43kW (hereafter AC) when located at one charging station, we hoped to see if there is a multistandard charging behaviour pattern which would have implications for further development of the infrastructure as well as its accompanying policy making.

CHAdeMO Association obtained a number of charging data points from four European operators of fast chargers that run each a national network of multistandard chargers: Rapid Charge Network (UK), Fastned (the Netherlands), Clever (Denmark), and Smartrics (Austria). We looked at the breakdown of kWh charged, total charging sessions, as well as the average session duration and kWh charged, all by connector type, and compared them with EV market share in the UK, the Netherlands, Denmark and Austria respectively. Our hypothesis was that the usage breakdown would strongly correlate with the local fast-chargeable EV market share by inlet and that the market trend would be a precursor of the near future charging infrastructure needs.

In the following section, we present the data we collected network by network. We start with a brief characteristic of each of the charging network, followed by a description of the EV market in the corresponding country and then show in more detail how their multistandard fast chargers are used. We conclude by extracting implications from the data.

There are some assumptions and limitations to our data analysis. First of all, as all of the four networks are spread throughout the country along the major routes enabling long-distance travelling from one end of the country to another, we assumed that the data set would provide valuable insights into how chargers are used in their respective country as a whole. Secondly, regarding the EV market share in this section, we look at fast-chargeable (above 22kW) passenger pure battery electric vehicles (BEV) only: AC (Renault ZOE), CCS (BMW i3; Volkswagen e-Up, e-Golf), CHAdeMO (Nissan Leaf, Mitsubishi i-MiEV, Citroën C-Zero, Peugeot

iOn, Kia Soul) and Tesla (Model S). This excludes non fast-chargeable BEVs, which account for 9% of all passenger BEVs in Europe [19]. We were also not able to separate CCS EVs with a fast charging option from those without. Given that the fast charging is not a standard equipment for many markets, CCS EV share may be over-represented. Lastly, as we have asked operators to prepare specific data for the purpose of this paper, we were not able to further our analysis as we did not have access to the raw data.

3.1 RCN

3.1.1 About RCN

Rapid Charge Network (RCN) is a charging network operating across UK (Ecotricity operates 95% of all RCN chargers) and Ireland (remaining 5%, operated by ESB eCars). It was partly funded by the European Union using the TEN-T scheme and supported by automakers: BMW, Nissan, Renault and Volkswagen. It is made up of 74 multistandard fast chargers each with one 44kW CHAdeMO, one 44 kW CCS and one AC connector. The chargers are deployed along key routes across the UK and Ireland, with the majority of the chargers placed at service stations on motorways.



Figure4: RCN charger locations

3.1.2 British EV market

Since Rapid Charge Network operates to a larger extent in the UK and the data collected concerned chargers deployed in the UK, for the purpose of this paper, the authors decided to only characterise the UK EV market.

With 1.1% of all car sales being a BEV or PHEV in 2015 [20], UK is one of Europe's leading EV markets with the total of 18,000 BEVs sold from 2013 to 2015 [19]. Thanks in part to the growing offer of EVs as well as the Plug-in Car Grant, which offers EV buyers an incentive of up to £5,000, the sales of EVs have been growing: in 2015, UK saw a 50.1% growth in BEV sales compared to 2014 [21]. Nissan Leaf is by far the most popular BEV, which means that in terms of fast charging inlet, CHAdeMO-compatible EVs are the most prevalent, followed by AC, Tesla and CCS EVs.

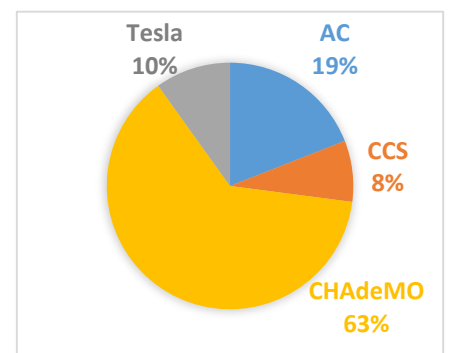


Figure5: UK BEV market

In addition to BEVs, the UK also has a large number of PHEVs, of which only Mitsubishi Outlander is equipped with a fast charging inlet (CHAdeMO). Mitsubishi Outlanders represent almost the equivalent of the total number of BEVs in the UK (not included in Figure 5).

3.1.3 Charger usage

Throughout the data collection period, from July 2014 to September 2015, CHAdeMO plugs have consistently delivered more energy compared to CCS and AC plugs, representing 75% of all sessions and 72% of all kWh charged, with CCS being 15% in both categories and AC 9% and 13% respectively.

When comparing the amount of kWh the users charged per session (Table2), there is a clear difference between the CCS and CHAdeMO EVs, with CCS drivers taking on average 11kWh, or 23% more energy than CHAdeMO at each charge, whereas for AC, the difference is much less pronounced (9.7kWh, 8% more than that of CHAdeMO drivers). At the same time, the charging session duration is very similar for the three types of connectors, with CCS and CHAdeMO being almost identical, and AC two minutes longer. One possible explanation for the little variation in the duration of charge despite a difference in the kWh charged between CCS and CHAdeMO can be the influence of Mitsubishi Outlanders. With their 12kWh battery, when they fast charge they not only require less energy, they also charge more slowly.

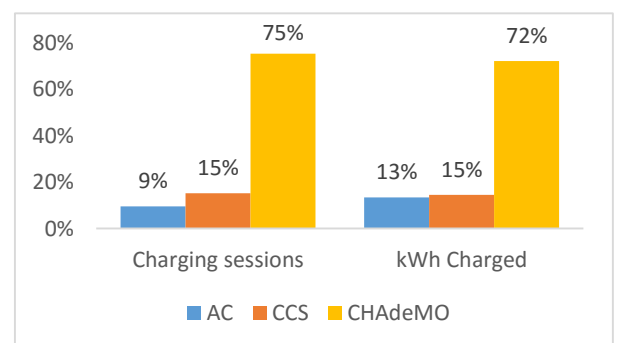


Figure6: RCN charger usage by connector

Table2: RCN energy transfer and time per transaction

	Energy per transaction (kWh)	Time per transaction (minutes)
AC	9.7	28.6
CCS	11.0	26.5
CHAdEMO	8.9	26.9

75% of charging sessions and 72% of the total energy delivered during the study period was via CHAdEMO connector. Taking into account a large number of Mitsubishi Outlanders and Teslas that can also use CHAdEMO via an adapter, we can say that this is quite in line with the CHAdEMO BEV market share, 63%.

CCS EV market share is 8% whereas the kWh and sessions charged represent 15% of all kWh and charging sessions registered by RCN. According to the project manager, Josey Wardle, this can be explained by the fact that CHAdEMO EVs have been in the UK market for much longer (since 2012); thus, many of their drivers can be considered seasoned and know their EVs and range well, whereas CCS drivers are new to the market and possibly feeling they need more electricity, more often [22]. This could be corroborated by the 23% difference in average kWh charged between CCS and CHAdEMO vehicles and by the data that while there are 8 times more CHAdEMO than CCS BEVs, the ratio of charging session per day between the two standards is 5 to 1.

All in all, and despite minor differences, it can be said that the UK multistandard charger usage by fast charging connector is in line with the BEVs market breakdown.

3.2 Fastned

3.2.1 About Fastned

The data from the Netherlands in this paper comes from Fastned, a privately owned Dutch fast charging station operator. Since late 2013, the company has deployed 50 stations across the Netherlands with another 80 in planning. Each Fastned station is located on a highway and comprises of 1 to 4 multistandard chargers. All of their stations have at least one CHAdEMO, CCS and AC connector [23].

3.2.2 Dutch EV market

Fastned operates in Europe's biggest plug-in market with over 43,000 units sold in 2015 only (183% growth compared to 2014) [24], including PHEVs. The sales are closely tied to government incentives which until the end of 2015 were the same for BEVs and PHEVs, resulting in a high number of PHEVs sold. Similar to the UK, Mitsubishi Outlander leads the sales of PHEVs with slightly over 20,000 units on the road [19]. In the BEV segment (8,585 units cumulative up to 2015) [19], Tesla Model S is the most sold vehicle (54%), followed by CHAdEMO BEVs with 28% share, AC (12%) and CCS (6%) as shown in Figure 8.



Figure7: Fastned charger locations

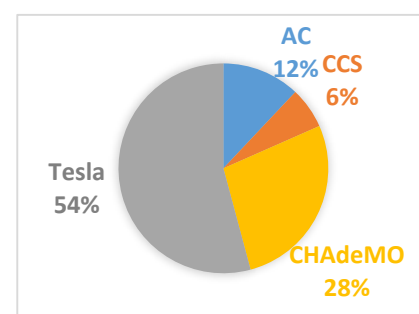


Figure8: Dutch BEV market

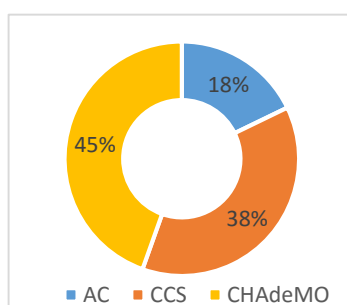


Figure9: Fastned kWh delivered by connector

3.2.3 Charger usage

Looking at kWh delivered by Fastned by connector type (Figure 9), we can see that according to data from early 2016, Fastned chargers delivered an almost equal amount of kWh to CHAdEMO (45%) and CCS (38%) cars, with 18% being delivered via AC connectors at their stations (the total does not up to 100% due to rounding).

Taking a closer look at the breakdown of CHAdEMO charging, we get more insights into the different types of CHAdEMO users (Table3). Indeed, one-half of all "CHAdEMO" customers using Fastned's service this year are Outlander users, and the rest almost equally split between Tesla and CHAdEMO BEV drivers. While there are nearly 4 times as many Outlanders

in the Netherlands as CHAdeMO BEVs, the Fastned user ratio of Outlander is lower because Outlander drivers can rely on their gasoline-powered generator. Similarly, Tesla drivers do not need as much fast charging support given their long autonomy, and because many of the Dutch Tesla drivers already had their EVs before Tesla CHAdeMO adapters came to the market in 2015, they use AC charging.

Table3: Fastned breakdown data of CHAdeMO charging

	Customers charged (%)	Number of sessions (%)	Total kWh charged (%)	Average kWh charged /session (kwh)	Average duration /session (min)
Outlanders	50	37	18	3.7	18
Tesla Model S	24	11	26	17.0	28
CHAdeMO BEVs	26	52	56	8.2	22

On the other hand, we see that CHAdeMO BEV users occupy the majority of CHAdeMO transactions and total kWh charged with 52% and 56% respectively. Tesla and Outlander users charge less frequently, and because the “small” Outlander sessions and “large” Tesla sessions (in both quantity and duration) somewhat cancel out, the breakdown of total kWh charged becomes CHAdeMO>Tesla>Outlander (56%, 26%, 18% respectively), and we can say that even in a country like the Netherlands with an important presence of Outlanders and Teslas, CHAdeMO BEV users’ behaviour characterises the usage of multistandard chargers in terms of number of transactions and total kWh charged.

Another interesting observation from the Fastned data set is a small difference between total kWh delivered via CHAdeMO and CCS connector (45% and 38%), which suggests that CCS fast charger usage is disproportionately high in the Fastned network. As there are more than twice as many CHAdeMO BEVs than CCS BEVs in the Netherlands, and add to that, CHAdeMO-chargeable Teslas and Mitsubishi Outlander PHEVs, which together, are four times as many as CCS and CHAdeMO EVs combined.

One possible reason to this, similar to the UK example, is that when people begin with an EV, they have more range anxiety and thus fast-charge more frequently and more electricity. Since CHAdeMO BEVs have been in-market since 2011 in the Netherlands, CHAdeMO EV drivers, in general, are more used to driving them compared to the CCS EV drivers. As shown in Table4, when we look at the state of charge (SoC) of the battery when starting and ending the charging session, we can see that CCS drivers charge more than CHAdeMO. While both CCS and CHAdeMO drivers start charging when their battery is on average, at 35%, CHAdeMO EV drivers stop charging when they reach 71%, and CCS EV drivers continue until 76%.

Table4: Average SoC at start/stop and % charged

	SoC (%) at start (a)	SoC (%) at stop (b)	% Charged (b) - (a)
CHAdeMO	35	71	36
CCS	35	76	41

Another possible explanation given by the operator [25] is that there are generally more CHAdeMO charge points than CCS charge points in the country, as the latter only started to be deployed in 2014. This means that CCS drivers have less “alternative” fast charging solutions and choose to use Fastned stations that are all equipped with CCS connectors.

However, looking at Fastned data, we can see that the market share and multistandard charger usage are not correlated, and that further look into the other elements, such as details of EVs in the market, e.g. fast-chargeable PHEVs, battery size and autonomy in the mix, is needed.

3.3 Clever

3.3.1 About Clever

Clever is a Danish operator of charging stations, from fast chargers on the main roads, through AC posts in cities to workplace charge points. They have been operating since 2012 starting with a complete network of 50 CHAdeMO-only chargers. They modified their network making it multistandard upon the arrival of CCS and AC fast-chargeable EVs. Clever now operates over 250 fast charging points primarily in Denmark, but also in Sweden and Germany [26].



Figure10: Clever charger locations

3.3.2 Danish EV market

The Danish EV market with over 5,800 pure EVs registered up to the end of 2015 [19], is unique in Europe because 95% of all plug-ins sold are BEVs [27]. This is due to the high tax rebates on BEVs that were in place until the end of 2015. Thanks to the incentives, Tesla Model S price was very attractive and the car was the most often purchased EV in the country last year. Anticipating the phasing out of rebates in 2016, Denmark saw a surge in sales of plug-ins in 2015, with a 190% year-on-year growth and EVs reaching 2.29% of market share [28].

In terms of fast-chargeable EVs, behind Tesla with 57%, CHAdeMO and CCS EVs have an almost equal inlet share (17% and 16%) with AC43kW representing the smallest market share of 10% [19]. This distribution is, however, likely to change in the near future. The cancellation of the incentives by the newly elected Danish government in 2016 means no more price difference between EVs and internal combustion engine cars, and many of the EVs doubled or even tripled in price, as in the case of Tesla Model S [29].

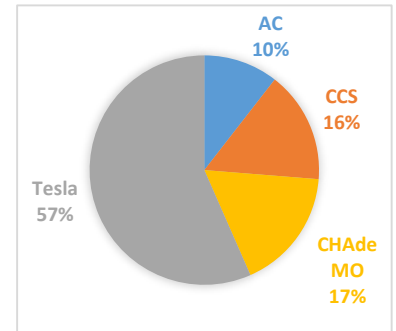


Figure11 Danish BEV market

3.3.3 Charger usage

Looking at the numbers from February 2016 shown in Figure12, we can see that, similarly to the RCN, CHAdeMO connectors are responsible for over three times more kWh as well as charging sessions than CCS, and four times more when compared with AC.

At the same time, in terms of kWh charged per session (Table5), AC users take in the most per charge, with 10.6kWh, followed by CHAdeMO (9.1kWh). Contrary to the data from RCN where CCS cars that charge the most, in Clever CCS cars charge the least and have the shortest charging session on average.

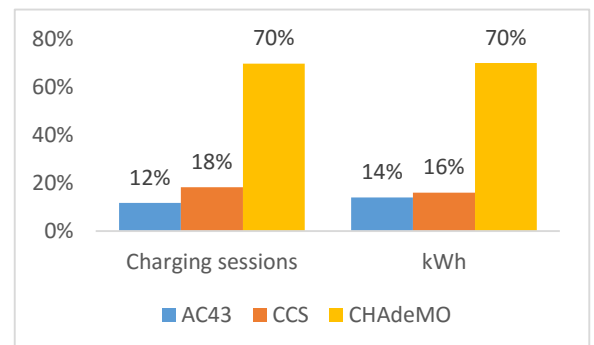


Figure12: Clever charger usage by connector

Table5: Clever energy transfer and time per transaction

	Energy per transaction (kWh)	Time per transaction (minutes)
AC	10.6	50
CCS	8.0	25
CHAdeMO	9.1	29

From the EV market share and charging data, we can see that unlike AC fast-chargeable EVs, CHAdeMO and CCS numbers are significantly different. Despite CHAdeMO and CCS having very similar EV market share (17% and 16% respectively), CHAdeMO delivered almost four times as much kWh as CCS. One reason may be that there are only 10 Tesla Supercharger stations in the country despite the high market share of Tesla Model S (57%). This suggests CHAdeMO charge points are heavily utilised by Tesla drivers via the CHAdeMO adapter, although we were not able to obtain the inlet type breakdown of CHAdeMO users.

As seen above, Danish multistandard usage also does not correlate with the market breakdown of EVs by fast charging inlet type, when we consider Tesla vehicles separate from CHAdeMO vehicles. Only when we

add the 57% of Tesla to 17% of CHAdeMO BEVs obtaining 74%, do we come close to the total kWh charged by Clever via CHAdeMO connector (70%).

3.4 Smartrics

3.4.1 About Smartrics

Smartrics is an Austrian e-mobility service provider that operates slow and fast chargers in Austria and Germany [30]. Similar to the RCN project, the development of Smartrics fast-charging network was partly funded by the European Union using the TEN-T Network funds (Central European Green Corridors (CEGC) project), with the participation of the automakers: BMW, Nissan, Renault and VW. The operator's network is comprised of 57 tri-standard chargers, 4 fast chargers with CHAdeMO-CCS outlets, 1 fast charger with CCS and Type 2 connector and 1 fast charger with CHAdeMO connector only in Austria, and 4 tri-standard chargers in Germany.



Figure13: Smartrics charger locations

3.4.2 Austrian EV market

Given that 95% Smartrics' chargers are in Austria, we take the Austrian EV market as a reference. While Austria is not the EU's top EV market, thanks to local subsidies, EVs have been enjoying steady sales growths over the past couple of years, with December 2015 seeing 23% increase in sales year on year [30]. Of its slightly over 3,200 vehicles sold from the beginning of 2013 to the end of 2015, AC fast-chargeable Renault ZOE's have the biggest BEV market share, followed by CCS vehicles, with Tesla and CHAdeMO EVs being relatively on par, with 21% and 20% of market share respectively [19].

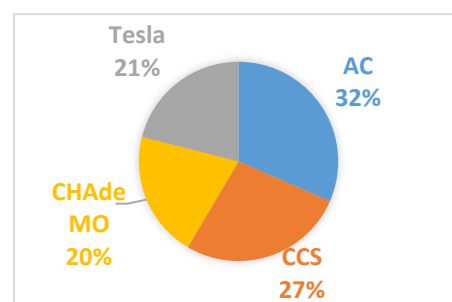


Figure14: Austrian BEV market

Contrary to the UK and Netherlands, the PHEVs remain a niche product and thus, their impact on fast charger usage is minimal.

3.4.3 Charger Usage

The charging data presented in this paper was collected from Smartrics' fast chargers from January to December 2015.

While we were not able to separate the AC22kW from 43kW connector data, as operators of multistandard chargers have one or the other, we can still see a clear trend in the way EV drivers charge in Austria.

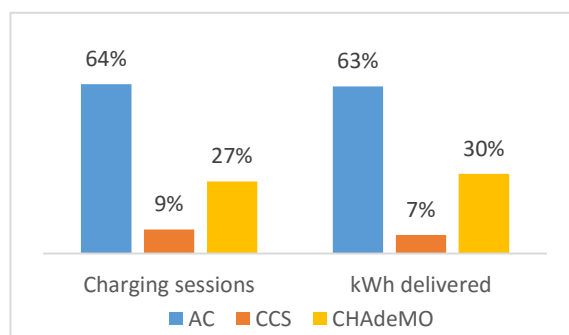


Figure15: Smartrics charger usage by connector

As we can see from Figures14 and 15, while CHAdeMO vehicles' market share (27%) and their usage of fast charging infrastructure roughly correlate, the same cannot be said about the other two protocols. AC fast-chargeable vehicles represent only 32% of vehicles in the country, but are responsible for twice as much charging sessions and kWh charged, whereas CCS, second most represented EVs by the plug, have used less than 10% of sessions and kWh. It can be argued that such a breakdown of charging is due to Teslas, which can charge with up to 22kW using the AC plug and, if in possession of an adapter, with the CHAdeMO plug.

This hypothesis is further corroborated when we look at the breakdown of the energy transfer and duration per session (Table6). As we can see, AC transactions are disproportionally long, lasting on average over two hours, whereas the other connectors deliver almost exactly-timed sessions of 33.1 min (CCS) and 33.9 min (CHAdeMO). This is likely due to Tesla EVs that have much larger batteries using their AC connector to charge, as the country only has 9 Tesla Supercharger stations.

Table6: Smartrics energy transfer and time per transaction

	Energy per transaction (kWh)	Time per transaction (minutes)
AC43kW and 22kW	11.4	122.3
CCS	8.9	33.1
CHAdEMO	12.8	33.9

When it comes to the kWh delivered, we get a different picture. The average kWh delivered by CCS are in line with other projects (8.9 kWh on average), whereas AC is slightly higher with 11.4kWh per session, likely due to Tesla users as per the above explanation. What stands out is the energy delivered on average via CHAdEMO connector (12.8 kWh), the highest of all projects. This is particularly high given that the majority of CHAdEMO EVs have batteries of less than 24kWh. However, taking into account the growing popularity of Tesla adapters, we can assume that this also is Tesla Model S drivers that are using CHAdEMO chargers and drawing significant amounts of energy per session.

Still, the Austrian fast charger usage is once again not in line with the EV market breakdown by inlet, if we look in terms of three standards: AC, CCS and CHAdEMO. However, if we assume that many of Tesla drivers (21%) use AC connectors together with the AC43 fast-chargeable EV drivers (32%), then we get close to the 64% of kWh delivered by AC plugs. And if we take into account that some of those drivers have CHAdEMO adapters, then we obtain an explanation for a higher proportion of CHAdEMO usage in the country.

3.5 Data analysis conclusions

At the outset of this data collection, it was expected that there would be a clear correlation between the market share of BEVs and the usage of multistandard chargers. However, as we can see from the above, the utilisation of the multistandard chargers is unequal in Europe and rarely correlates with the market breakdown of BEVs. It is heavily dependent on the market and the presence (or not) of 1. fast-chargeable plug-ins, 2. EVs that can charge with one or more of the fast charging connectors or via adapters (Teslas), as well as 3. other external factors such as the general availability of a particular connector in a given market or how experienced the drivers of a given EV group are.

4 Implications for policy, charger operations and technology

Electric vehicle fast-charging market is very new, unstable and heavily dependent on the number and types of EVs sold, which in turn partly depend on the national incentives, but is also influenced by individual customer choices. Under these circumstances and from our analysis, the below can be said for future policy making, fast-charging operations and technology development.

4.1.1 Policymakers

From our data, we can conclude that the operators' task of optimising the usage of their network is in no case simple. The private sector has been leading, and will lead the EV charging infrastructure operations. Given that it is hardly profitable, operators should be provided all flexibility there is to define the infrastructure they put in place in the most productive way possible, reflecting the local market and thus maximizing their revenues. This requires a flexible legal environment that does not define which and how many of a given plug there must be. Needless to say, public policy should stay technology neutral as a principle, and when the legal system imposes a single connector that does not reflect the idiosyncrasies of a given market, it reduces the ability of operators to define how many of which type of connector they offer with a given charger and thus can impact their profitability and long-term viability. This can hinder the development of e-mobility as a whole.

4.1.2 Charger operators

It is one thing that the more experienced drivers may charge more efficiently as we have seen in some of the data. On the operators' side, apart from optimising the types of chargers and accompanying connectors they deploy, further measures to increase the efficiency of their operations will be key to their success. While we

did not touch on the pricing side of charging in this paper, one method to increase operation efficiency can be through their pricing scheme changes that would encourage certain EV charging behaviours and discourage others, such as long charging (two hours of AC fast charge in Austria), so that it would resolve queueing issues that begin to appear in certain charger locations. Another solution could be via information technology to provide real-time charger utilisation status that indicates the availability of a given charger.

4.1.3 Technology providers

CHAdEMO and other technology protocols would also have to flexibly evolve with the market needs. For example, below are examples of the changes CHAdEMO has activated along the way and those that are upcoming.

- Simultaneous charging: as the EV market grows and operators need to flexibly adapt to the changing charging needs, CHAdEMO has allowed dynamic current control from its version 1.0.1. This enables CHAdEMO fast chargers to simultaneously charge multiple EVs, helping their operators achieve further charger usage optimisation.
- Higher power charging: with the market evolution for higher battery capacity, CHAdEMO is already close to standardising its new generation protocol that enables +150 kW charge (up to 350A). The new generation CHAdEMO chargers can be expected soon.

In conclusion, we were not able to demonstrate that the multistandard charger usage correlated with the local BEV market share. On the contrary, what the data told us was much more complex and we can see that none of the four European markets had many traits in common. With the EV market and its charging infrastructure deployment still at the nascent stage, the fast charging needs and usage remain still very unequal and unpredictable. Therefore, all stakeholders need to remain alert and adapt to the ever-changing market demands and robust and flexible legal, operational and technological support is indispensable in order to accelerate the growth and development of the EV market.

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