Future transport energy mix and EV-infrastructure requirements

Project Acronym:	**eMAP**
Project Full Title:	**electromobility – scenario based Market potential, Assessment and Policy options**
Dissemination level:	**PU**
Lead beneficiary:	**BAST Federal Highway Research Institute**
Start of Project:	**July 2012**
Duration:	**33 months**

Document Information

Deliverable:	**D5.2 Report on future transport energy mix and EV-infrastructure requirements**
Lead author:	**Florian Kleiner (DLR)**
Status of deliverable:	**final version**
Due date of deliverable:	**March 26th, 2015**
Actual submission date:	**March 26th, 2015**
Funding Code / Agreement No.:	**BAST: 03EMEN02A** **DLR: 03EMEN02B** **VTT: 00CG8-0018741** **ITS: ELECTROMOBILITY+/1/NCBR/2012**

Version Control and Revisions

Version	Date	Authors	Reviewers	Status
draft V4.0	January 16th, 2015	FK	Auvinen, Heidi (VTT) Klötzke, Matthias (DLR)	initial draft version
draft V5.0	February 24th, 2015	FK	Auvinen, Heidi (VTT) Järvi, Tuuli (VTT) Kurte, Judith (KE-Consult) Bühne, Jan-André (BAST) Klötzke, Matthias (DLR)	extended draft version
final	March 25th, 2015	FK, JB, JT, HA	Bühne, Jan-André (BAST)	final version

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Approval:

All partners of the project consortium via a return email have approved the final version of this eMAP Deliverable.

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1 Introduction

1.1 Background

The European Commission states that transport in Europe is 94 % dependent on oil products of which 84 % are imported (EC 2013). This implies substantial cost for the oil import which causes a deficit in the balance of trade (EC 2013). In addition, oil supply is mainly provided by politically unstable regions raising security concerns (EC 2013). By the introduction of alternative fuels, savings on the oil import bill, growth of jobs, improvements in air quality and reduction of noise are expected (EC 2013). One of the European Commission's Transport 2050 Strategy goals is to reduce up to 50 % the use of conventionally fueled cars in urban transport by 2030, with focus on the most congested areas. It also proposes a target of 60 % greenhouse gas emissions reduction by 2050 (EC 2013a). Main barriers for the full-scale market penetration of electric vehicles are the high retail cost, a low level of consumer acceptance and the lack of infrastructure for recharging or refueling (EC 2013a). For these reasons investors avoid the risk as they don't see enough vehicles on offer and eventually on the streets. Hence, the costs of the infrastructure installations and powertrain technologies for EVs are still on a high level, as economies of scale are lacking. Available technologies are hybrid electric, battery electric or fuel cell electric powertrains. In contrary to hybrid and battery powertrain technologies, only one passenger car equipped with a fuel cell electric powertrain is currently available on offer (Frieske et al. 2015). The overall market penetration of fuel cell electric vehicles is expected to remain marginal within the time frame considered in the eMAP project (Plötz et al. 2013, Brokate et al. 2013, Propfe et al. 2013, Kugler et al. 2015, Adolf et al. 2014). Additionally, current European Union (EU) regulation states that the built-up of publicly accessible hydrogen infrastructure should only be pursued if hydrogen is considered in the national policy framework (EC 2014).

1.2 Objectives and report structure

This analysis aims to define the required charging infrastructure for electric vehicle technologies and to outline country specific attempts, which impacts the future fuel and energy mix for the transport sector. Due to the aforementioned reasons, hydrogen is not taken into account in the analysis of the technology assessment and the outline of the energy mix. Through expert interviews a validation of the insights gained from literature research was expected. Unfortunately, the results of the interviews are not representative based on low expert participation and response.
The report focuses on different stationary charging opportunities for battery electric vehicles. Starting from today's availability, announced infrastructure targets are assessed and existing plans are described to get a clear picture of the current situation and the prospective charging infrastructure developments necessary in the eMAP Partner countries. Subsequently, different stationary charging technologies are explained and available cost data is presented. Finally, expected future development trends regarding the electricity- and fuel mix used for electric and conventional driving will be described based on national plans

for the countries under assessment. Regarding the evaluation of scenarios for electromobility with an integrated quantitative assessment and multi criteria analysis, the cost data presented within this report is used for the cost benefit and stakeholder analysis.

2 Assessment of current EV recharging infrastructure and future development plans

2.1 The present EV recharging infrastructure

For common understanding the following definitions are used and based on the latest directive of the European Commission regarding the deployment of alternative fuels infrastructure.

- "*'electric vehicle'* means a motor vehicle equipped with a powertrain containing at least one non-peripheral electric machine as energy converter with an electric rechargeable energy storage system, which can be recharged externally" (EC 2014)
- "*'recharging point'* means an interface that is capable of charging one electric vehicle at a time or exchanging a battery of one electric vehicle at a time" (EC 2014)

The situation of charging points for electric vehicles (EVs) varies greatly across the EU. As to 2011 the European Commission reported 11.749 existing charging points in the EU (EC 2013a). ARF and McKinsey (2014) reported more than 20,000 public accessible charging posts throughout Europe by 2013. Different charging modes e.g. normal and fast charging as well as different types of connectors exist. Within section 3 technical specifications, relevant for Europe, will be explained in detail. At an electric charging post at least one electric vehicle can be charged. Therefore, charging points available at one charging post is at least one but can also be two or more. The countries of focus for the analysis in this report are the eMAP Partner countries Finland, Germany and Poland. All data given refers to recharging points. Integrity of the data given cannot be guaranteed.

2.1.1 Finland

In November 2014, 389 public accessible charging points exist according to the Finnish online database keeping track of public charging points (Sähköinen liikenne 2014). In addition, there are private outlets installed at private residential and work place car parks or places for winter warming of both the engine and the interior of the car. Presently there are around 1.5 million cars with block heaters installed (nearly 60% of the Finnish car fleet) that can utilize this possibility in addition to garages (IA-HEV 2015b). No battery swap stations presently exist (Sähköinen liikenne 2014). In Table 1 numbers of available charging types are separated into type of power transfer and accessibility. Fields of the tables are left blank, if no further information is available.

Table 1: Number of charging points and battery swap stations in Finland in 2014 (Sähköinen liikenne 2014)

charging mode	energy transmission	accessibility		
		public	private	total
normal power charging	by wire	347		347
	wireless			
high power charging	by wire	42		42
	wireless			
Total charging points		389		389
battery swap station				

2.1.2 Germany

As to 2011 the number of existing charging points reported account for 1,937 (EC 2014). Updated in January 2014, Table 2 contains the number of charging points and battery swap stations in Germany. In total, 30,000 charging points exits, whereof 4,720 are public accessible (NPE 2014). Furthermore, none public battery swap station for passenger cars is available.

Table 2: Number of charging points and battery swap stations in Germany in 2014 (NPE 2014)

charging mode	type of energy transfer	accessibility		
		public	private	total
normal power charging	by wire			
	wireless			
high power charging	by wire			
	wireless			
total charging points		4,720	25,280	30,000
battery swap station		0	0	0

2.1.3 Poland

Regarding the year 2011, the European Commission reported 27 existing charging points (EC 2013a). Table 3 contains the number of charging points and battery swap stations in Poland as reported by the project partners. In 2014, therefore, 30 charging points and none battery swap station exist.

Table 3: Number of charging points and battery swap stations in Poland in 2014 (EEO 2014b)

charging mode	type of energy transfer	accessibility		
		public	private	total
normal power charging	by wire			30
	wireless			
high power charging	by wire			
	wireless			
total charging points				30
battery swap station				

2.2 Proposed targets for electric vehicle infrastructure deployment

Concerning the establishment of an adequate EV infrastructure network across the continent, the European Union (EU) emphasizes the importance of national development plans and concentrates on the creation of common technical specifications and the support of national measures, from research to market penetration (EC 2013). The proposal for a directive on the deployment of alternative fuels infrastructure of the European Parliament and of the Council, "aims at ensuring the build-up of alternative fuel infrastructure and the implementation of common technical specifications for this infrastructure in the Union" (EC 2013b). Based on formula (1), the proposal includes minimum infrastructure coverage by the year 2020 for battery electric vehicles (EC 2013b).

$$NCP_i = \frac{CS_i}{CS_{EU}} \cdot \frac{UP_i}{UP_{EU}} \cdot EVS_{EU} \cdot 2 \qquad (1)$$

$NCP = Number\ of\ charging\ points\ needed$
$i = Member\ State\ (e.g. FI, DE, PL)$
$CS = Car\ stock$
$EU = European\ Union$
$UP = Share\ of\ urban\ Population$
$EVS = EV\ stock$

Within Table 4 the minimum number of electric vehicle recharging points for the eMAP Partner countries are presented according to EC (2013b). Numbers of recharging points for each Member State i are calculated by using Formula (1). 10 % of the calculated number of recharging points has to be publicly accessible (EC 2013b).

Table 4: Minimum number of electric vehicle recharging points by 2020 for eMAP Partner countries (EC 2013b)

Members States	Number of recharging points (in thousands)	Number of publicly accessible recharging points (in thousands)
Finland	71	7[a)]
Germany	1,503	150
Poland	460	46

a) As reported by the partners, the Finish authorities revised the minimum number of public accessible recharging points based on the latest directive mentioned in the following sections 2.3 and 2.3.1.

2.3 Future EV recharging infrastructure development plans

The final directive EC (2014) adopted by the European Parliament and the Council on 29th September 2014 (EC 2014a) does not include the proposed quantified targets. In general, via the final directive the European Commission ensures progress in terms of:

- the development of national policy frameworks for the market development of alternative fuels and their infrastructure;
- the use of common technical specifications for recharging and refueling stations;
- the setup of appropriate consumer information on alternative fuel. (EC 2014a)

Required results and timings to be met by the Member States, relevant for this study, are presented within Table 5.

Table 5: Required results and timings relevant for this study according to EC (2014)

Result	Timings
National policy framework based on required contents as described within Article 3 of EC (2014)	18th November 2016
Report on the implementation of its national policy framework based on the required contents as described within Annex I of EC (2014)	18th November 2019 (and every year three years thereafter)
Appropriate number of publically accessible recharging points in urban/suburban and other densely populated areas	31st December 2020

Within the scope of the report on the implementation of its national policy framework of each Member State, estimations of the number of alternative fuel vehicles expected by 2015, 2020 and 2030 have to be made. As mentioned before, quantified targets as proposed within EC (2013b) for recharging points are not included within the directive EC (2014), instead, recommend minimum numbers of public accessible recharging points is stated as "[…]Member States should ensure that recharging points accessible to the public are built up with adequate coverage, in order to enable electric vehicles to circulate at least in urban/suburban agglomerations and other densely populated areas, and, where

appropriate, within networks determined by the Member States. The number of such recharging points should be established taking into account the number of electric vehicles estimated to be registered by the end of 2020 in each Member State. As an indication, the appropriate average number of recharging points should be equivalent to at least one recharging point per 10 cars, also taking into consideration the type of cars, charging technology and available private recharging points. […]" (EC 2014).
Based on the insights gathered so far, current situation of the eMAP Partner countries will be discussed in the following.

2.3.1 Finland

Finland has no official targets for the penetration of electric cars as the policy for energy efficiency is technology neutral. However, in achieving the national target for CO_2 reduction of 80 % in transport by 2050 from the 1990 level (Governmental report on climate policy, Valtioneuvosto 2009), electromobility still plays an important role. A target of 30 % of road kilometres driven with electricity by 2050 has been recommended by a national working group commissioned by the Minister of Transport in 2012 (MINTC 2013). In addition, the EU regulation of average CO_2-emissions for new registered passenger cars in 2020 to be under 95g/km is a target in Finland as well.

Present infrastructure findings as of 2014 correspond to approx. 0.6 % of the proposed total recharging point target set by the European Commission for the year 2020. For public charging points, the aim is to comply with the EU directive of 7,000 by the year 2020 (presently the target achievement is approx. at 5.6 %). However, the EU has recently decided to drop the targets and revise the bill so as not to enforce any binding contracts. Some interpretations of the directive estimate the Finnish EU-based target to translate into around 4,000 charging points for the year 2020. Regarding private charging points in Finland, the infrastructure i.e. electricity outlets at private car parks and places to overcome the Nordic winter climate conditions could be used for EV charging (IA-HEV 2015b). However, at car parks updating of the infrastructure would be needed to serve several EVs simultaneously. Nonetheless, according to the directive EC (2014), the required number of charging points depends on the estimation of the registered battery electric vehicles by the year 2020. By end 2014, the number of registered electric vehicles amount to 929 in total (Trafi 2015). Based on the recommendation made within EC (2014) regarding the minimum number of public accessible recharging points, mentioned above, the number of necessary recharging points amount to 93 so far. As national policy supports a strong market share for biofuels, a large number of EVs will not necessarily be needed to meet the vehicle emission reduction targets set for 2020 (IA-HEV 2015). Nevertheless, several stakeholders including cities have announced plans for infrastructure buildup for electric vehicles, both for cars and buses (IA-HEV 2013).

2.3.2 Germany

National targets set regarding the total number of electric vehicles are 1,000,000 by the year 2020 (EC 2013a). Furthermore, as to the total number of charging points, the target set by 2020 is 1,503,000 whereof 150,000 should be public accessible (EC 2013b). Present infrastructure findings as of 2014 correspond to approx. 2.0 % of the total number of recharging point target set by the German Government for the year 2020. Additionally 1,473,000 charging points are required. Regarding publicly accessible recharging points target achievement is approx. at 3.2 % when taking the European Commission target of 150,000 public accessible charging points into account. In order to achieve the target, additional 145,280 public charging points are required. However, according to the directive EC (2014), the required number of charging points depends on the estimation of the registered battery electric vehicles by the year 2020. Registered electric vehicles amount to 24,000 in total (NPE 2014). Based on the recommendation made within EC (2014) regarding the minimum number of public accessible recharging points, mentioned above, necessary recharging points amount to 2,400 so far. Minimum public accessible charging points needed by 2020 are 100,000 based on the target set, 1,000,000 registered electric vehicles by 2020. Current total infrastructure planning (scenario pro) as reported within NPE (2014) foresee 1,203,000 charging points by 2020. Currently, several projects are promoting further charging infrastructure deployment (DDI 2014). Additional projects are in process of planning aiming to strengthen investment partnerships regarding the buildup of public available charging points (NPE 2014). The market preparation phase (2010-2014) is over and from 2015 until 2017 the market launch takes place (NPE 2014). The vision and roadmap of the national platform of electromobility (NPE) clearly illustrates future activities and priority areas for action regarding the different thematic areas: Vehicle Technology, Energy & Environment, Charging Infrastructure and Urban Planning & Intermodality (NPE 2013). Figure 1 and Figure 2 illustrates the vision and roadmap for different sub-categories regarding the charging infrastructure thematic. In early January 2015, the Federal Ministry of Economics and Technology proposed a draft regarding the technical specification of public accessible charging points (BMS 2015).

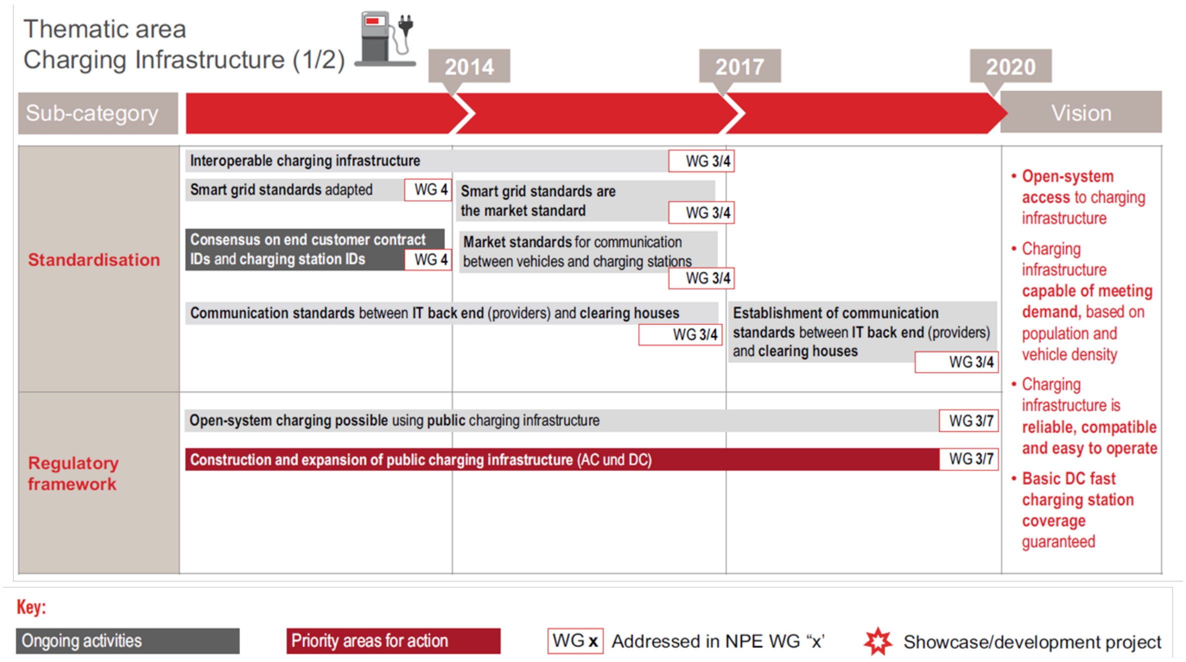


Figure 1: Charging infrastructure vision and roadmap (1/2) (NPE 2013)

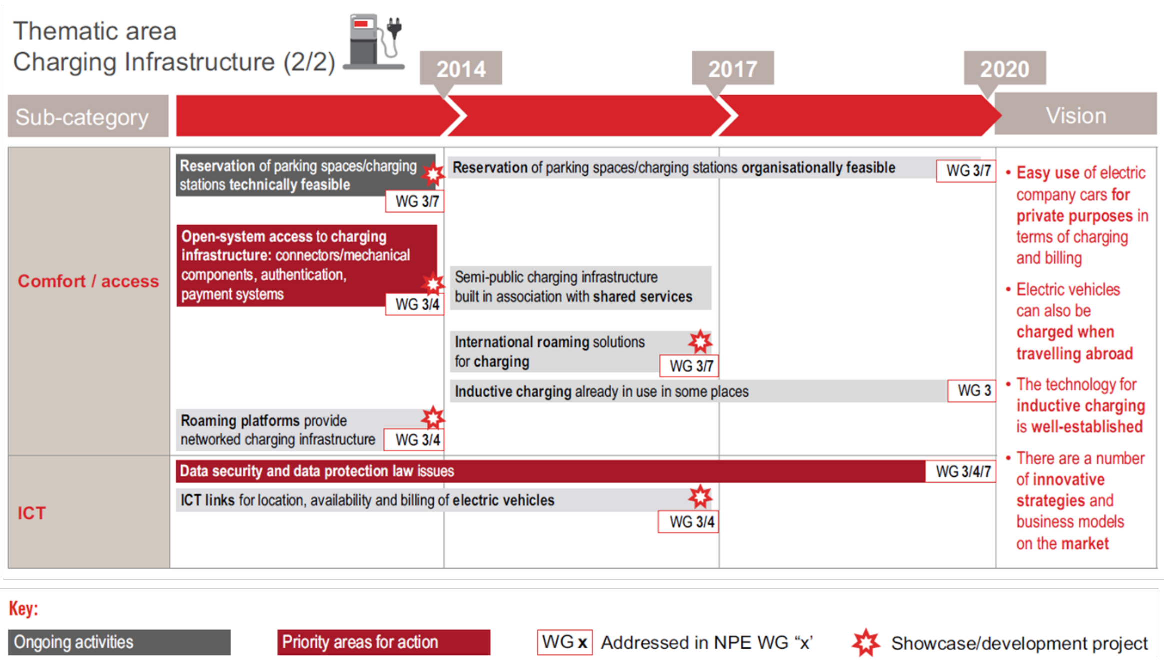


Figure 2: Charging infrastructure vision and roadmap (2/2) (NPE 2013)

2.3.3 Poland

Poland has not set a specific target regarding the number of electric vehicles and the number of charging points in total or public accessible. Present infrastructure findings as of 2014 correspond to approx. 0.01 % of the proposed total recharging point target set by the European Commission for the year 2020. Additionally 459,970 charging points are required. Regarding publicly accessible recharging points target, the achievement is approx. at 0.07 % when assuming that the present infrastructure findings are public accessible and when taking the European Commission targets into account. In order to achieve the target, additional 45,970 public charging points are required. According to the Commission Staff working document EC (2013c), the infrastructure target mentioned was 300 charging points by 2013, whereof 27 are public accessible. As reported by the partners there may be about 2,000 public charging points by 2020. However, according to the directive EC (2014), the required number of public accessible recharging points depends on the estimation of the registered battery electric vehicles by the year 2020. Updated in November 2013, registered electric vehicles amount to about 70 in total (EE0 2014). Based on the recommendation made within EC (2014) regarding the minimum number of public accessible recharging points, mentioned above, necessary recharging points amount to 7 so far. In general, Warsaw launched the public support for infrastructure electromobility in 2009. Especially, the Warsaw City Hall is anxious to implement pilot projects covering the buildup of charging infrastructure (EC 2013c).

3 EV recharging infrastructure technology

3.1 Plug-in recharging

Based on the insights of section 2 plug-in charging clearly dominates the other approaches in terms of the scale of deployment and, therefore, is the most important charging technology. According to Figure 3, plug-in charging process is able to take place by the use of either alternating current (AC) or direct current (DC). The Battery requires to be charged by direct current. In the case of AC-charging an on-board charging unit converting the AC supply into a DC supply is necessary (BMVI 2014). In the case of DC-charging an off-board charging unit provides the required DC supply necessary for the vehicles battery (BMVI 2014). In addition, four different connector types and four different charging modes exist by taking international standards of Europe, USA and Japan into account (NPE 2014), (BMVI 2014). Only Tesla as a battery electric vehicle manufacturer offers special charging solutions to their customer. To allow for public recharging, Tesla customers have to invest in adapter for country individual standards (Tesla 2015).

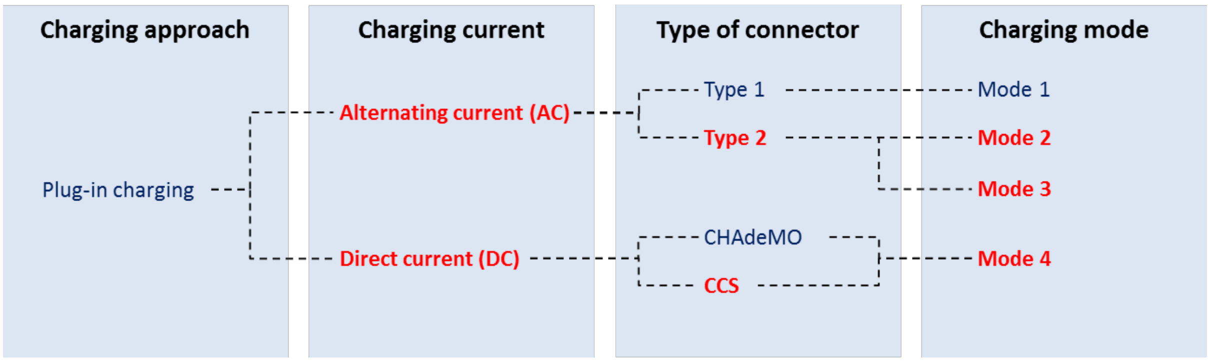


Figure 3: Plug-in charging process opportunities (BMVI 2014)

The common European standard connector is Type 2 for AC-charging and Combo 2 for DC-charging according to EC (2014). Standard connectors and combined charging system (CCS) inlet are illustrated within Figure 4. Additionally, CHAdeMO officially becomes a European standard by the European Committee for Electrotechnical Standardization (CENELEC) but is not proposed as Union-wide common connector (CHAdeMO 2014), (EC 2104).

Type 2 | Combo 2 | CCS-inlet (Combo 2 & Type 2)

Figure 4: European standard connectors and CCS-inlet (BMVI 2014)

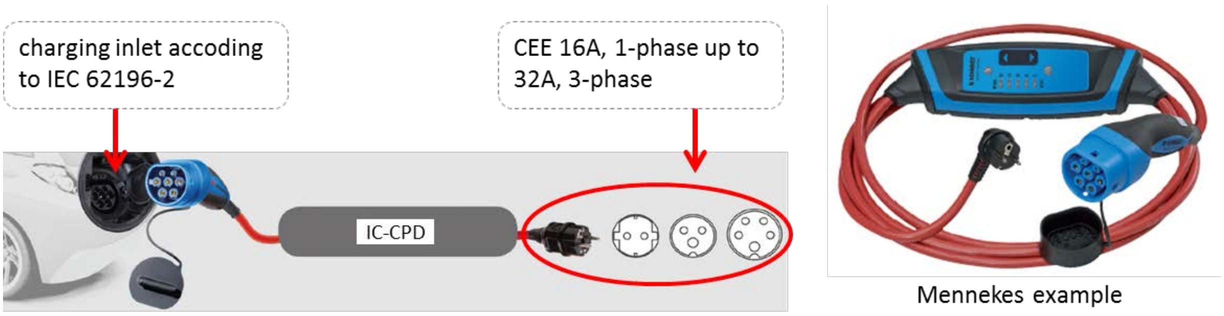
As illustrated within Figure 3 the Type 2 connector allow for charging modes 2 and 3. Table 6 gives an overview of their characteristics.

Table 6: Overview of charging mode 2 and mode 3 characteristics (BMVI 2014)

Charging mode		Mode 2	Mode 3
Communication		PWM-modul in charging cable	PWM[a)]-modul in charging post
Interlock		at vehicle	at vehicle and charging point
Power	1-phase	max. 16 A, 3.7 kW	max. 16 A, 3.7 kW
	3-phase	max. 32 A, 22.0 kW	max. 63 A, 43.6 kW

[a)] PWM: pulse width modulation

Mode 2 corresponds to the normal power recharging point definition and Mode 3 corresponds to the high power recharging definition, which both are given in EC (2014). For Mode 2 charging an in-cable control and protection device (IC-CPD) is required (BMVI 2014). Figure 5 illustrates the charger connection by Mode 2 and Type 2 connector.



Mennekes example

Figure 5: Charger connection by Mode 2 and Type 2 (BMVI 2014), (MENN 2012)

For Mode 3 charging an Electric Vehicle Supply Equipment (EVSE), with standard charging device according to the International Electrotechnical Commission (IEC) 61851 specifications, is required (BMVI 2014). The EVSE includes PWM-communication, error and excess current protection, emergency cut-out in the case of power breakdown and a specific charging outlet (BMVI 2014). Figure 6 illustrates the charger connection by Mode 3 and Type 2 connector.

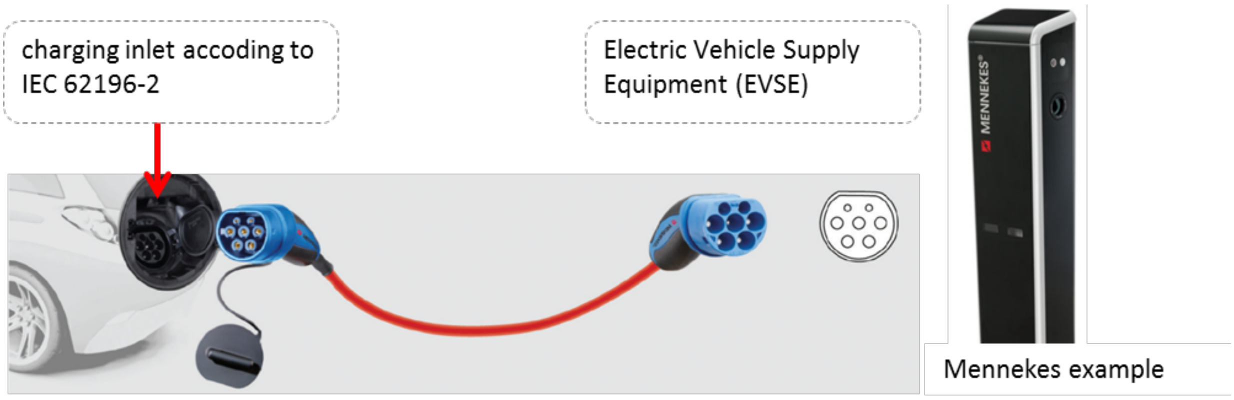


Figure 6: Charger connection by Mode 3 and Type 2 (BMVI 2014), (MENN 2012)

Beside the AC-charging modes 2 and 3, DC-charging mode 4 exists. As mentioned at the beginning, in contrast to AC-charging, the charging unit of DC-charging is off-board and, therefore, integrated within the EVSE. Relevant for the European market are the connector types CHAdeMO and Combo 2 (BMVI 2014). Only the Combo 2 is compatible for the Combined Charging System (CCS). According to the EC (2014) European wide proposed standard is the Combo 2 connector. Therefore, only the combined charging system is explained in more detail. The use of the combined charging system allows not only for DC-charging but also for AC-charging via type 2 connector. The CCS-inlet is presented within Figure 4. Currently, the CCS standardization is in progress by IEC 62196-3 which is the reason for not clearly defined limits of the available maximum power transfer yet (BMVI 2014). But, basically, two options of charging are possible as shown within Figure 7. According to BMVI (2014) DC-Low charging allows a maximum power of 38 kW (80 A) via type 2 connector. DC-High charging allows a maximum power of 170 kW (200 A) via combo 2 connector (BMVI 2014). As mentioned beforehand CCS standardization is currently in progress and a maximum power transfer is not clearly defined, yet. Therefore, data given are guideline values according to BMVI (2014).

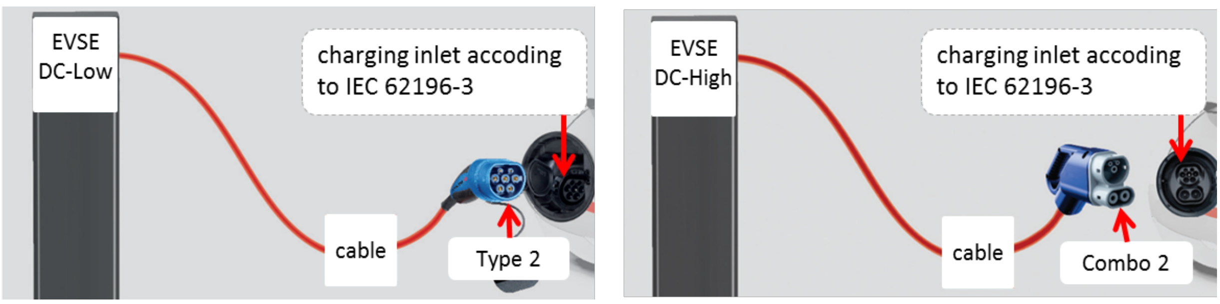


Figure 7: Charger connection by Mode 4 Type 2 and Combo 2 respectively (BMVI 2014)

Main advantages of the Combined Charging System over CHAdeMO are:

- Only one inlet is sufficient to allow for AC- and DC-charging.
- By the use of CCS via combo 2 maximum power transfer of up to 170 kW is feasible. CHAdeMO only allows, technically feasible, 62.5 kW as maximum at present. (BMVI 2014)

In general, the charging technology described above can be offered for private (e.g. parking block), semi-public (e.g. service area) and public (e.g. roadside) usage whereof all charging site examples named in brackets are public accessible (NPE 2014). Not public accessible charging sites are located either at domestic areas or company sites (NPE 2014). Table 7 contains the net-costs for public accessible Plug-in charging technology according to NPE (2014). Table 8 shows the net-costs for private Plug-in charging technology according to Plötz et al. (2013).

Table 7: Net-costs in EUR of public accessible Plug-in charging technology according to NPE (2014)

Plug-in recharging technology	Wallbox (publ. lamp)	EVSE (normal power charging)	EVSE (high power charging)
Type of current	AC	AC	DC
Smart meter and energy management	no	yes	no
Charging points	1	2	1
Power rating in kW	3.7	11/22.2	22-50
Charging post hardware Communication hardware Payment and control applied logic	2,200 €	6,000 €	20,000 €
Installation	300 €	4,500 €	7,150 €
Total investment	2,500 €	10,500 €	27,150 €
Approval for special application		150 €	
Maintenance	350 €	500 €	2,000 €
Communication	200 €	200 €	200 €
Metering/Payment	375 €	375 €	375 €
IT-system	250 €	500 €	500 €
Yearly running expenses	1,175 €	1,725 €	3,075 €
Yearly overheads	not taken into account		
Depreciation period in years	7.5		

Table 8: Net-costs in EUR of private Plug-in charging technology according to Plötz et al. (2013)

Plug-in recharging technology	Wallbox1	Wallbox2	Wallbox3
Type of current	AC	AC	AC
Smart meter and energy management	no	no	yes
Charging points	1	1	1
Power rating in kW	3.7	11/22.2	11/22.2
Charging post hardware	200 €	600 €	2,000 €
Communication hardware			
Payment and control applied logic			
Installation	300 €	500 €	500 €
Total investment	500 €	1,100 €	2,500 €
Approval for special application	-	-	-
Maintenance	-	-	-
Communication	-	-	-
Metering/Payment	-	-	-
IT-system	-	-	-
Yearly running expenses	-	-	-

At present, the total investment costs are at a high level which is expected to decrease by increasing the production units. Referring to Plötz et al. (2013) the assumed cost degression rates are 5 % per annum for AC charging post hardware, communication hardware, payment and control applied logic. Regarding DC charging post hardware, communication hardware and payment and control applied logic, a degression rate of 9.5 % per annum is assumed (Plötz et al. 2013). Over a seven-year period, maximum degression rate in total is set to 50 % (Plötz et al. 2013). As a reason for different degression rates, low quantities of present DC-EVSE are mentioned. Running costs are estimated to decrease yearly by 3 % (Plötz et al. 2013).

3.2 Wireless recharging

Inductive Power Transfer (IPT) or Wireless Power Transfer (WPT) systems enable electric power transfer via a magnetic field between two inductively coupled resonators (coils) (Pantic 2013). Figure 8 illustrates stationary wireless chargers. To prevent the coil from hazardous situations it is covered with plastic as shown within the Witricity example (Pantic 2013). Furthermore, the primary plate can either placed above the ground or underground (Boer et al. 2013).

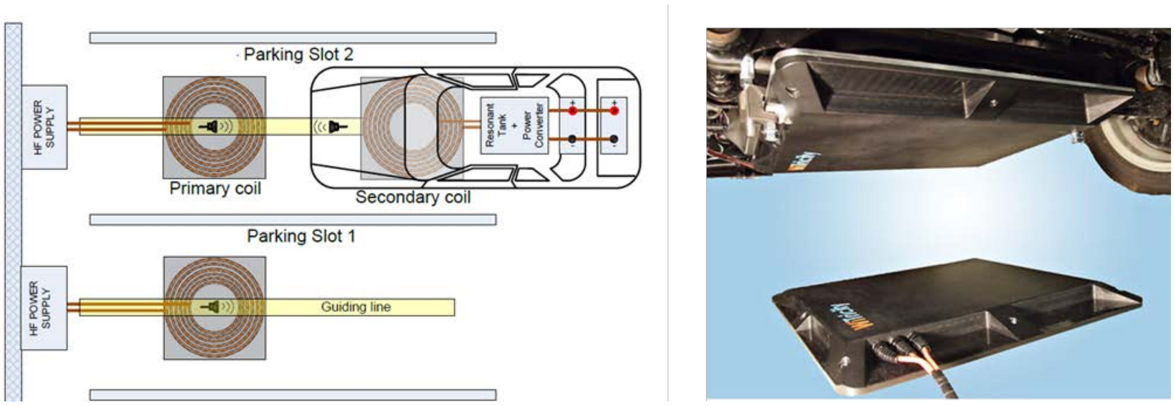


Figure 8: left: Stationary wireless charging (Pantic 2013); right: Witricity charging system example (Ifak 2011)

In contrary to Plug-in solutions wireless energy transfer solutions are rarely available at the market due to the current research status of this recharging technology. Different research projects with German industry involvement, started or already terminated, investigate ideal concepts of wireless energy transfer (BMVI 2014), (Boer et al. 2013). Only for standardization regarding the power transfer of 3.7 kW good progresses has been made. This is not the case for power transfer rates of 7.2 kW, 11 kW or 22 kW respectively (BMVI 2014) and, thus, further investigations are necessary. For this reason cost figures do rarely exist. However, within Table 9 the available literature values are summarized.

Table 9: Net-Costs in EUR of wireless charging technology according to Ifak (2011) and Kley (2011)

	Ifak (2011)	Kley (2011)
Charging points	1	
Power rating in kW	3.6	3.7
Vehicle hardware	500 € - 1,000 €	1,400 € - 2,500 €
Charging post hardware	900 € - 1,650 €	1,500 € - 2,500 €
Communication hardware	not available	1,000 € - 2,000 €
Payment and control applied logic	350 €	500 € - 1,000 €
Installation	not available	2,000 € - 3,000 €
Total investment	1,750 € - 3,000 €	6,400 € - 11,000 €
Yearly running expenses	not available	785 € - 2,470 €

The large cost data bandwidth given in Table 9 illustrates the present high degree of uncertainty. For this reason after the standardization progress is accomplished and the wireless power transfer technology is out of the research and development phase and, thus, ready for series application the cost values has to be revised.

3.3 Battery swapping

To drastically reduce the recharging time, addressed as one major limitation to the widespread adoption of electric vehicles according to Mak et al. (2012), the battery swapping concept was developed by Better Place. Figure 9 illustrates the concept of a fully automated battery swap.

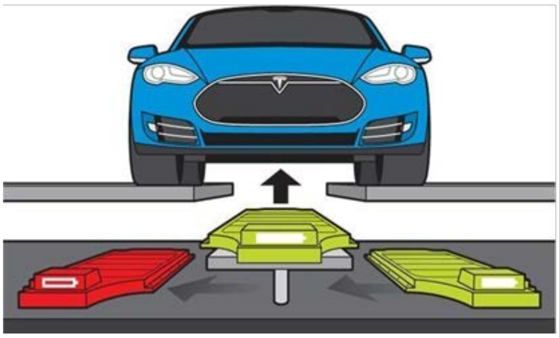



Figure 9: left: Fully automated battery swap (AT 2014); right: Battery swapping station in Tokyo (MM 2013)

The concept allows for exchanging the depleted battery for a fully charge one and, therefore, reduce the recharging time from a couple of hours to a few minutes (Kley 2011). This concept requires a standardization of the battery and its placement across manufacturers (Kley 2011). The existents of different types and sizes of batteries would require a stock that is sufficient to ensure battery availability for each vehicle which results in high investment costs (Kley 2011). Due to the variety of different battery types and technical requirements, battery standardization is unlikely (Kley 2011). The fact that the electric vehicle owner will only own the vehicle and not the battery decrease the vehicle investment but also could lead to inconsiderate battery usage due to current battery used could simply be replaced by another one (Kley 2011). Battery swapping station investment costs are mainly based on oral statements from the chief executive officers of Better Place and Tesla. Both of them mentioned approx. 380.000 € per station (ME 2013), (Yarow 2009). However, Better Place went bankrupt in 2013 (MM 2013). Only Tesla still promotes this concept and offers battery swapping for invited Model S owners to test technology and assess demand (ME 2013), (AT 2014), (Tesla 2014). Costs to the customer according to Tesla amount to approx. 45 € - 55 € and, thus, equivalent to the refueling costs of a sedan (Domes 2015).

4 Future fuel and energy mix of the transport sector

4.1 Finland

Finland's Transport sector accounted for 17.2 % (50 TWh) of the total final energy consumption in 2011, which is the lowest percentage of the among the IEA member countries (IEA 2013). Government forecasts indicate a reduction to 12.6 % in 2020 (IEA 2013). Furthermore, to reduce the transport related GHG emissions, Finland's target for renewable energy for fuels used in transport is 20 % by 2020 (IEA 2013). In particular, fuel tax reforms should ensure decreasing emissions of new cars by linking the tax to the energy and carbon content of transport fuels (IEA 2013). The act on biofuel distribution obligation (446/2007 and amendment 1420/2010) additionally supports the renewable energy share target regarding the transport sector as a further example (IEA 2013). Currently, the transport sector mainly depends on oil (IEA 2013). Biofuels represents just 4.2 % of energy consumption in 2011, whereas natural gas (0.3 %) and electricity are negligible (1 %) (IEA 2013). To reach the target of 10 % (5.9 TWh) energy savings by 2020 in comparison to the level of 2010, further advances in vehicle and fuel technologies are required (IEA 2013). According to the National Energy and Climate Strategy, synthetic natural gas made of biological raw material can possibly be used as a transport fuel. In addition, Finland aims at a 10 % substitution of natural gas with synthetic natural gas by 2025 (NECS 2013).

To reduce oil dependency in the energy mix, the Climate and Energy Strategy highlights the biofuel blending obligation, increasing energy efficiency in general and transport based on electricity as key measures (NECS 2013). In 2011, renewable energy sources represented 33.6 % (24 TWh) of total electricity supply, ranking Finland the ninth among IEA member countries in terms of the share of power generated from renewable sources (IEA 2013). The main renewable source for electricity, by 50 % (12.5 TWh) share, was hydropower, followed by biofuels with a 46 % (solid biomass account for 43 %) share (IEA 2013). Wind and the remaining sources account for 2 % each (IEA 2013). However, electricity generation using wind power is expected to increase considerably by 2020 (IEA 2013). According to VTT clean energy technology strategies for society, "biomass to biomass based products and energy is one of the most competitive solutions" and, therefore, expected to increase considerably regarding electricity generation by 2020 as well (VTT 2012), (IEA 2013). Further expansion of hydropower is very limited (IEA 2013). Carbon capture and storage (CCS) is seen as a new option technically feasible for reaching a low carbon economy at the highest greenhouse gas reduction costs (VTT 2012). In addition, Finland plans to increase the amount of electricity from combined heat power (CHP) plants at all scales (VTT 2012). Nuclear power is seen as backbone of low carbon electricity production according to VTT (2012), future capacity is increasing. In 2010, the parliament already accepted two additional nuclear power plants (VTT 2012). Thus, capacity will be increased.

4.2 Germany

In 2011, Germany's total final consumption (TFC) was 2,570 TWh, whereof the transport sector accounted for 24.5 % (630 TWh) (IEA 2013a). By 41.6 % of TFC oil products, mainly consumed by the transport sector, account for the largest share (IEA 2013a). Natural gas and electricity accounted for 23.2 % and 20.3 % respectively. Others like Biofuels with a share of 6.2 %, heat with a share of 4.5 % and coal with a share of 3.7 % are less significant in final use (IEA 2013a). 49.7 % of the total oil supply in 2011 was consumed by the transport sector which is equal to 85 % of the transport sectors TFC (IEA 2013a). Inland consumption of natural gas used in the transport sector is 0.9 %, but is expected to increase as more GHG efficient fuel (IEA 2013a). Electricity consumption as well as Biofuels and waste accounted for 3.2 % and 10.9 % respectively. Forecasts expect an increase of the electricity consumption within the transport sector by nearly 100 % caused by an increase of electric vehicles marked share and mobility measures (IEA 2013a). Germany, as the largest GHG emitter in the European Union, has decoupled GHG emissions from economic growth (IEA 2013a). In 2011, the transport sector account for 19.9 %, approx. 182 Mt CO_2-equvivalent (IEA 2013a). Germany's target, regarding the year 2020, is to cut GHG emissions by 40 %, compared to the level of the year 1990 (IEA 2013a). In addition, a reduction of final energy consumption in the transport sector by 10 % is aimed to achieve in 2020 (base year: 2008) (IEA 2013a). In order to reach the targets set, the federal government developed a "mobility and fuel strategy", accomplished and presented in 2013, with focus on alternative fuel use and the establishment of renewable energy in the transport sector (IEA 2013a). According to IEA (2013a) the most cost-efficient way to fulfil its 10 % renewable target in transport fuels is the use of biofuels. It has to be taken into account that some biofuels on the market may not qualify to count towards the 10 % target as they do not meet the minimum GHG thresholds (IEA 2013a). Via the biofuel quota act, a minimum level of biofuels has to be used in road transport (IEA 2013a). The biofuels sustainability law ensures that the used biofuels lead to a certain percentage of GHG emission savings compared to fossil fuels (IEA 2013a). Currently at least 35 % GHG emission savings, 50 % starting 2017 and 60 % from 2018 have to be reached (FNR 2011). Furthermore, ecologically sensitive areas like wetlands or rain forest for example has not to be considered for biofuel production. Only if sustainability standards are met, biofuel is considered regarding the biofuel quota (IEA 2013a). Diesel substitution with biodiesel is limited since the production capacity in Germany is roughly 4.9 Mt per year and current domestic consumption of biodiesel accounts for 2.58 Mt per year (IEA 2013a). Germany reorganizes its energy supply by phasing out nuclear power until the end of 2022 and expanding renewable energy sources. For this reason a comprehensive package of legislation was adopted in 2011 (IEA 2013a). The target is to increase the share of electricity generated from renewable energy sources from approx. 17 % in 2010 to at least 80 % by 2050 (IEA 2013a). In 2011, electricity generation from renewable sources was approx. 132 TWh which corresponds to 22 % of the total primary energy supply (IEA 2013a). From renewables the most significant share provided wind power (48.9 TWh) as well as biofuels and waste (44 TWh) (IEA 2013a). Electricity generation made of renewable sources is expected to continue to grow to 58 % by 2030 with the greatest increase of 200 % to come from wind power (IEA 2013a). Wind power will account for 30.6 % of total electricity in 2030, followed by biofuels at 13.3 %, solar at 9 % and hydro at 5.2 % Geothermal will remain at a negligible level of less than 0.5 % (IEA 2013a).

4.3 Poland

Due to the strong dependence of Poland's crude oil imports, mainly from Russia, the government aims to diversify import sources (IEA 2011). To reduce its import dependence and to change its future fuel mix, Poland maximizes the use of existing domestic energy resources by supporting oil and gas exploration activities (IEA 2011).
In 2009, Poland's total final energy consumption reached a level of approx. 756 TWh, whereof the transport sector accounts for 24 % (182 TWh) (IEA 2011), (Enerdata 2011). Transport sectors total final energy consumption share increased from 11 % in 1990 to 24 % in 2009 due to considerable challenges of passenger light-duty vehicle ownership (Enerdata 2011), (IEA 2011). As a result, 60 % of the total oil consumption in 2009 related to the transport sector and is expected to increase in the future (IEA 2011). Limited policies are in place to counteract the expected emission increase of the transport sector (IEA 2011). The "Long-Term Biofuel Promotion Programme 2008-2014" aims to improve the competitiveness of biofuels by supply and demand-side measures such as exemption from parking fees and obligations for public administrations to use biofuels (IEA 2011). The "Bio components and Liquid Biofuels Law of 25 August 2006" ensure that a certain percentage of fuel sales come from renewable sources as from 2008 (IEA 2011). However, future energy policy is guided by EU requirements to increase the share of renewable energy to 15 % of gross final energy consumption by 2020 (IEA 2011). Additionally, 10 % of energy use in transport has to be performed with biofuels or other renewable energy sources (IEA 2011). Within the second National Energy Efficiency Plan (NEEAP), final energy reduction target of 11 % (67.2 TWh) by 2016 is set, whereof 24 % (16.1 TWh) should be reached of the transport sector (Enerdata 2013). According to IEA (2011), 2 % of renewable energy (biofuels) was used for the transport sector in 2006. By 2030 the government projects an increase to 15 % (IEA 2011). Therefore, further energy policy aims to promoting renewable energy technologies especially biomass (IEA 2011). Existing support mechanisms for the electricity and transport sectors such as the certificates of origin, biofuels obligations and excise duty exemptions retain (IEA 2011). Additional support regarding biogas plants, offshore wind farms, utilization of biodegradable waste and hydropower are in process of planning (IEA 2011). In 2009, renewable based electricity accounted for 5.8 % (IEA 2011). Based on Poland's key policy document "Energy Policy of Poland until 2030 (EPP 2030)", which was adopted in 2009, diversification of the electricity generation structure by introducing nuclear energy and the development of the use of renewable energy sources (including biofuels) are key directions (IEA 2013). Poland plans to build-up at least three nuclear power plants by 2030 for reducing its carbon intensity (IEA 2011). Furthermore, by investments in new electricity capacity like renewables and natural gas additionally reduces the carbon intensity (IEA 2011).

5 Conclusions

The insights of the assessment of current EV recharging infrastructure and future development plans clearly show that the charging infrastructure deployments throughout the eMAP partner countries Finland, Germany and Poland currently are in the early stages. Regarding the scale of deployment, plug-in charging is the most important charging technology in contrast to wireless charging and battery swapping as further recharging solutions. Compared to the today's number of public charging points in Finland 5.6 %, in Germany 3.2 %, and in Poland 0.07 % of the minimum charging infrastructure requirements are reached. However, according to the approved directive "on the deployment of alternative fuels infrastructure" enacted in the end of 2014, minimum requires public accessible recharging points depending on the number of electric vehicles estimated to be registered by the end of 2020. Minimum required number of recharging points should be equivalent to one recharging point per ten cars. Common European standard connector is Type 2 for AC-charging and Combo 2 for DC-charging. In order to have appropriate number of publically accessible recharging points in urban/suburban and other densely populated areas available by the end of 2020, member states are forced to develop national policy frameworks until the end of 2016 and to report on its implementation until the end of 2019. Therefore, considerable progress in terms the market development of recharging points, the use of common technical specifications and the setup of appropriate user information is expected by early 2017. Up to now, the Partner Countries have not announced national policies yet.

The future fuel and energy mix of the transport sector is likely to remain dependent on oil throughout the eMAP partner countries. All countries focus on the use of biofuels as most efficient way to fulfill renewable targets. In addition, all countries plan the expansion of renewable energy sources depending on country individual resources and possibilities. Nuclear power is seen as backbone of low carbon electricity production in Finland. Even Poland plans to build-up new nuclear power plans for reducing its carbon intensity. Therefore, only Germany reorganizes its energy supply by phasing out nuclear power and significantly expanding renewable energy sources especially wind power.

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