Development Scenarios for E-Mobility in Europe

UDO BACHHIESL & NIKOLAS KORDASCH

Abstract This paper presents development scenarios for e-mobility in Europe. The analysis of the initial situation shows, that key factors such as climate change or dependence on oil in the mobility sector call for a promotion of e-mobility globally and in Europe. This development is influenced by given targets in the European Union regarding alternative mobility. Furthermore, the fundamental aspects of e-mobility like the advantages and disadvantages or the different types of vehicles are introduced. With the help of recent sales numbers the European EV market has been divided into battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) and has been analysed in detail for each country for the years 2011 to 2015. Based on this data, an in-depth research on the countries' promotion and support measures regarding e-mobility has been conducted. The global e-mobility targets (IEA2DS, IEA4DS, Paris Declaration) are converted into European targets and in relation to these targets three different scenarios (LOW, MEDIUM and HIGH) have been developed. These scenarios describe the growth of the EV market from 2016 to 2030 and are based on the actual numbers of EV. In addition, by using predefined average values for the EV the power consumption of the EV has been calculated and put in relation to the overall power consumption of the countries for every year until 2030. Concluding a summary of the present supporting measures of the investigated European countries for EV will be given in this paper.

Keywords: • e-mobility • Europe • development scenario • BEV • PHEV •

CORRESPONDENCE ADDRESS: Udo Bachhiesl, Graz University of Technology, Institute of Electricity Economics and Energy Innovation, Inffeldgasse 18, 8010 Graz/Austria, e-mail: www.iee.tugraz.at. Nikolas Kordasch, Graz University of Technology, Institute of Electricity Economics and Energy Innovation, Inffeldgasse 18, 8010 Graz/Austria, e-mail: bachhiesl@tugraz.at.

https://doi.org/10.18690/978-961-286-071-4.9 ISBN 978-961-286-071-4

Available at: http://press.um.si.

1 Introduction

The energy economical world will have to change in the future in order to fight the ongoing climate change. A major cause for the climate change is the rising concentration of manmade greenhouse gases (GHG) in the atmosphere, mostly coming from burning of fossil fuels. Within the different GHG carbon dioxide (CO_2) plays beside of methane an important role. Figure 9.1 shows a comparison of the different major sources of CO_2 emissions on a global level and in Austria.

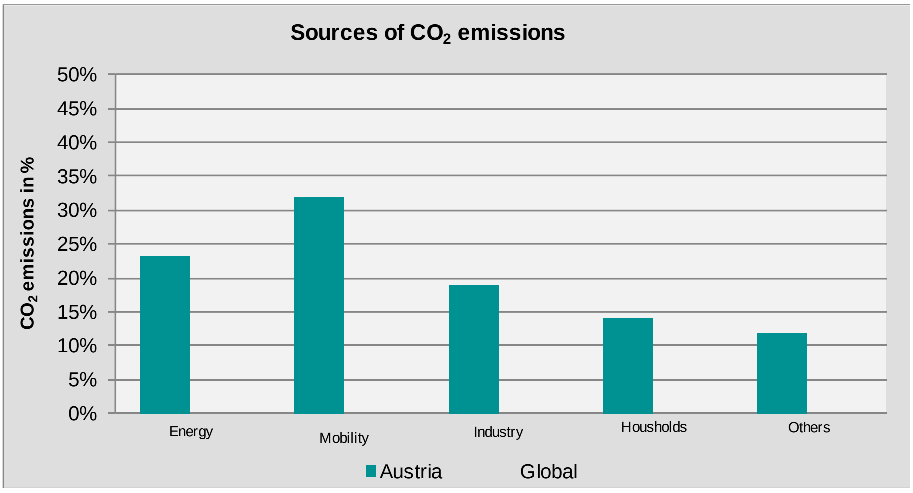

Figure 9.1. Sources of CO_2 emissions [1]

Figure 9.1 shows that at the global scale the energy sector is responsible for about 45 % of the CO_2 emissions, followed with nearly one quarter coming from the mobility sector and followed by industry and households. In Austria - because of the big share of electricity coming from hydropower plants - the situation differs and the mobility sector is with 32 % of the overall CO_2 emissions in the lead followed by the energy sector with 23 %. This short analysis shows, that the mobility sector will have to play an important role, if we want to reduce the CO_2 emissions substantially. The emissions will not remain stable at the present level, because it is to be expected, that especially the mobility sector is still growing rapidly especially in the BRICS (Brazil, Russia, India, China, South Africa) countries. Also according to the United Nations Framework Convention on Climate Change, 21st Conference of the Parties (COP21) it is expected that the emissions in this sector will rise about 20% up to the year 2030 and about 50% up to the year 2050. [2]

In the case of Austria, the emissions from the mobility sector account for about one third of the overall emissions of 67,9 million tonnes CO_2 equivalent, which corresponds to 32 million tonnes CO_2 equivalent. [3] Fig 2 shows the composition of the GHG emissions in Austria in 2014 and it can be seen that CO_2 emissions account for 85 % followed by the CH_4 emissions with 7 %.

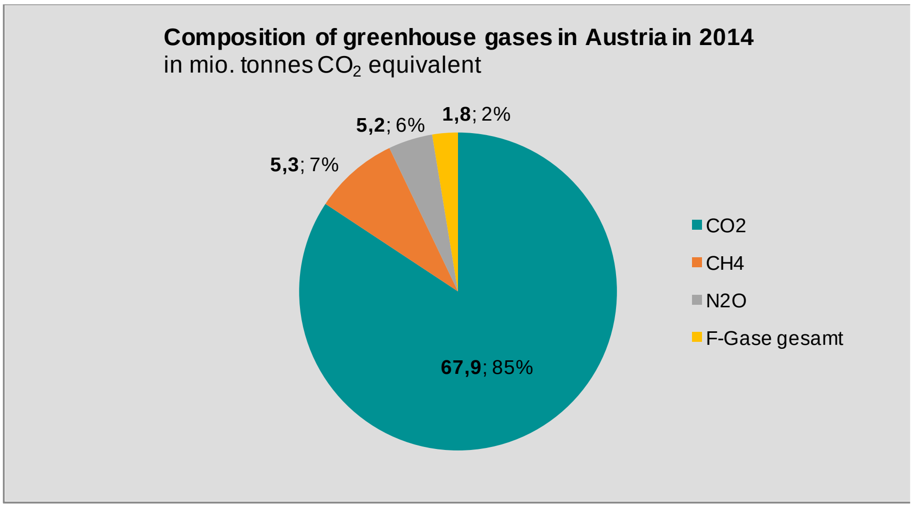

Figure 9.2. Composition of GHG emissions in Austria in 2014 [3]

Since several decades the world community has tried to react against the mentioned development, starting in 1979 with the first world climate conference and the following signature of the United Nations climate treaty in 1992. 1997 started the implementation of the Kyoto protocol which entered into force in 2005 and should cover the period from 1990-2012 but since a replacement treaty has been missing it has been prolonged to 2020. In 2015 the UN climate conference took place in Paris and the agreement has been signed by 175 states in April 2016 and with the coverage of 55 states and 55% of the global emissions it went into force in November 2016. The agreement should lead to a limitation of the global warming below 1,5°C, a complete decarbonisation until 2045-2060 with no burning of fossil fuels and 100% electricity from renewables from 2040 on.

As shown before the mobility sector is highly relevant for reaching the desired targets. One future option is the large-scale introduction of EV with an electricity supply based on renewable energies. Within the EU legislation exist different targets regarding the mobility sector, some of indirect and some of direct manner. The indirect targets cover the present targets of the energy strategy up to the year 2020 regarding GHG reduction (40%), the share of renewable energy (27%) and the improvement of energy efficiency (27%). As long term target a reduction of the GHG emissions of 80 to 95% up to the year 2050 has been settled. Direct targets are e.g. covered by the white book mobility of the European Commission [4]. The goals of the white book cover a bisection of the conventional vehicles for city logistics up to 2030 and up to the year 2050 no more conventional vehicles in the city logistics. There also exist passages within the Paris declaration on electro-mobility and climate change. According to calculations of the International Energy Agency (IEA) at least 20% of the fossil fuel based transport sector has to be switched to e-mobility in order to reach the 2 °C target. The overall share of EV has to reach 35 % up to the year 2030.

2 Fundamentals of E-Mobility

As has been shown in the first chapter, it will be only possible to reach the climate targets if we are able to reduce the emissions from the mobility sector worldwide. Figure 9.3 shows the average CO_2 emissions of new passenger cars in Europe and although the emission limits have been reduced since the last decades this measure alone will not be sufficient enough.

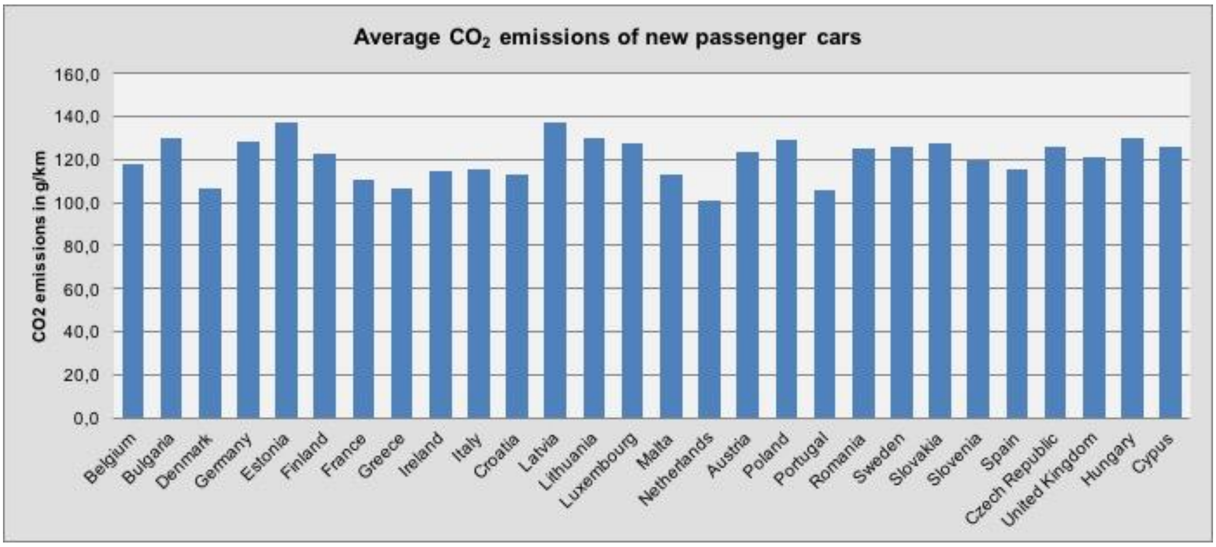

Figure 9.3 Average CO_2 emissions of new passenger cars in Europe

There are several alternatives for the future mobility which comprise biofuels, super ethanol, natural gas and CNG, hydrogen, hybrid concepts as well as pure EV. This paper focuses on EV and following some of the major advantages of EV will be given:

- Energy efficient drivetrain
- Reduction of local emissions
- Loudness
- Torque
- Simplicity of drivetrain
- Cheap operation and maintenance costs

Although there are several advantages one has to consider also the disadvantages of e-mobility and some of them are listed below:

- High initial investment costs
- Range
- Charging time
- Loudness

There are different options for using electricity in the mobility sector like Mild Hybrid Electric Vehicle (MHEV), Full Hybrid Electric Vehicle (FHEV), Plug-in Hybrid Electric Vehicle (PHEV), electric cars with range extender, Battery Electric Vehicles (BEV) or Fuel cell (FC) cars. Table 9.1 gives an overview of different properties of the mentioned driving options.

Table 9.1: Properties of different alternative propulsion systems

Type	Model	Power		Battery	Charging	Consumption	CO2 emission	Range		Price*
		Electric	Gasoline					electric	total	
		[kW]	[kW]	[kWh]		[l / 100 km]	[g/km]	[km]	[km]	[€]
Mild-Hybrid (MHEV)	Mercedes S 400	20	225	1	recup.	6	139	-	-	98550
Full-Hybrid (FHEV)	Toyota Prius	53	72	1,3	ICE, recup.	3	70	2	-	29900
Plug-In Hybrid (PHEV)	Toyota Prius PH	18	72	5	230V, recup.	2,1	49	30	-	37920
Range Extender	Opel Ampera	115	63	16,5	230V, ICE	1,2	27	40 - 80	500	38400
Battery electric vehicle (BEV)	Mitsubishi i-MiEV	49	-	16	230V, recup.	-	0*	160	160	34000
	Tesla Roadster	183	-	53	230V, recup.	-	0*	200-300	200-300	128000
Fuel Cell (FC)	Mercedes B (F Cell)	65	-	1,4	FC, recup.	3,3	0**	400	400	-

* if using renewable energies for electricity production

** produces H2 emissions

ICE…Internal combustion engine, FC…Fuel Cell, recup…Recuperation

Figure 9.4 shows the CO_2 emissions of the mentioned alternative driving technologies, assuming that the directly used electricity for charging comes from renewable energies without causing CO_2 emissions.

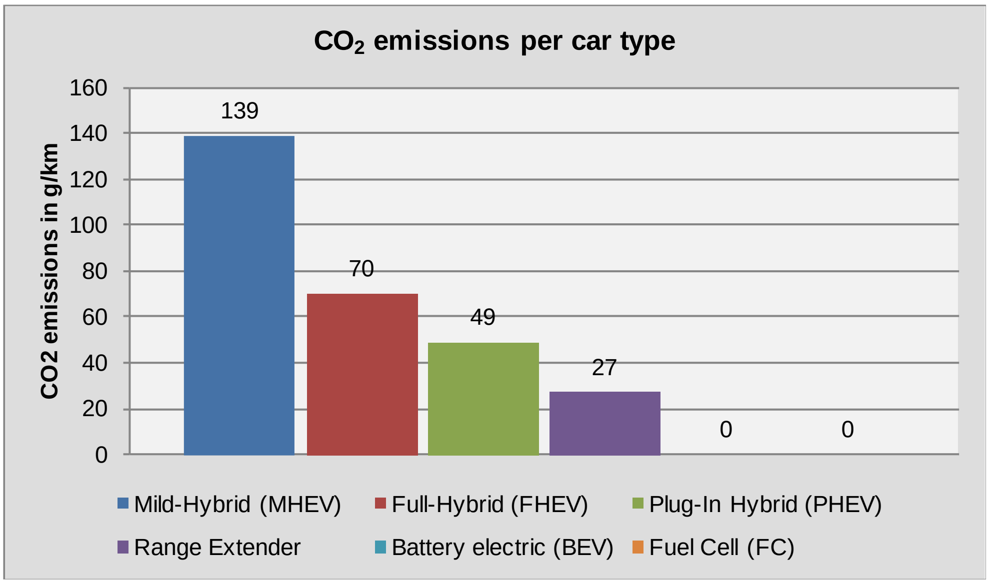

Figure 9.4 CO_2 emissions of the compared alternative driving technologies

3 Status of E-Mobility in Europe

This chapter gives an overview of the status of e-mobility in Europe. The analysis has been done for every single European country and is based on many different national sources and complemented by some general publications. Those publications are e.g. the “Global Electric Vehicle Outlook 2016” of the IEA [5], data from the European-Alternative Fuels Observatory Homepage [6] and permission data of the European Automobile Manufacturer Association [7]. The status in the single countries is very different reaches from nearly 0% to 2% and therefore the countries have been divided into two groups with less than 0,1% and more than 0,1% of market share. The result of this analysis is given in Table 9.2.

.

Table 9.2 Overview of the e-mobility status in Europe

EUROPE 2015					
	BEV	PlugIN	Total EV	Licensed	Market share
Liechtenstein	0	0	0	0	0,00%
Hungary	0	0	0	3.671.663	0,00%
Bulgaria	10	7	17	3.605.000	0,00%
Romania	31	47	78	5.915.630	0,00%
Turkey	119	108	227	15.143.756	0,00%
Poland	157	249	406	24.476.852	0,00%
Lithuania	29	20	49	2.151.813	0,00%
Caprus	4	29	33	583.692	0,01%
Greece	126	252	378	6.423.343	0,01%
Latvia	59	13	72	764.422	0,01%
Croatia	113	48	161	1.605.927	0,01%
Italy	3.802	1.256	5.058	41.905.560	0,01%
Czech Republik	623	179	802	5.766.175	0,01%
Slovakia	193	144	337	2.343.922	0,01%
Malta	56	5	61	324.360	0,02%
Spain	4.045	1.434	5.479	26.954.473	0,02%
Slowenia	193	67	260	1.174.723	0,02%
Portugal	1.215	711	1.926	5.635.860	0,03%
Finland	507	988	1.495	3.853.008	0,04%
Ireland	837	135	972	2.265.940	0,04%
Germany	29.374	18.519	47.893	48.202.108	0,10%
Belgium	3.582	3.924	7.506	6.391.644	0,12%
Austria	4.380	1.765	6.145	5.209.228	0,12%
United Kingdom	20.875	28.117	48.992	37.608.358	0,13%
France	43.863	9.023	52.886	38.521.667	0,14%
Estonia	1.053	25	1.078	780.016	0,14%
Luxembourg	541	224	765	425.571	0,18%
Switzerland	6.120	3.965	10.085	4.916.609	0,21%
Denmark	6.697	532	7.229	2.815.552	0,26%
Sweden	4.766	10.890	15.656	5.253.288	0,30%
Island	682	235	917	261.710	0,35%
Netherlands	9.970	78.260	88.230	9.342.400	0,94%
Norway	58.097	10.154	68.251	3.189.187	2,14%
Total	**202.119**	**171.325**	**373.444**	**317.483.456**	

In 2015 there have been in sum 202.119 BEV and 171.325 PHEV on the road in Europe which totally represents an overall share of just about 1%.

Aside the concrete numbers given in Table 9.2 Figure 9.5 shows a graphical representation of the results. In order to get a better overview, the classification has been redefined into five sections which are shown in different colours in the graph.

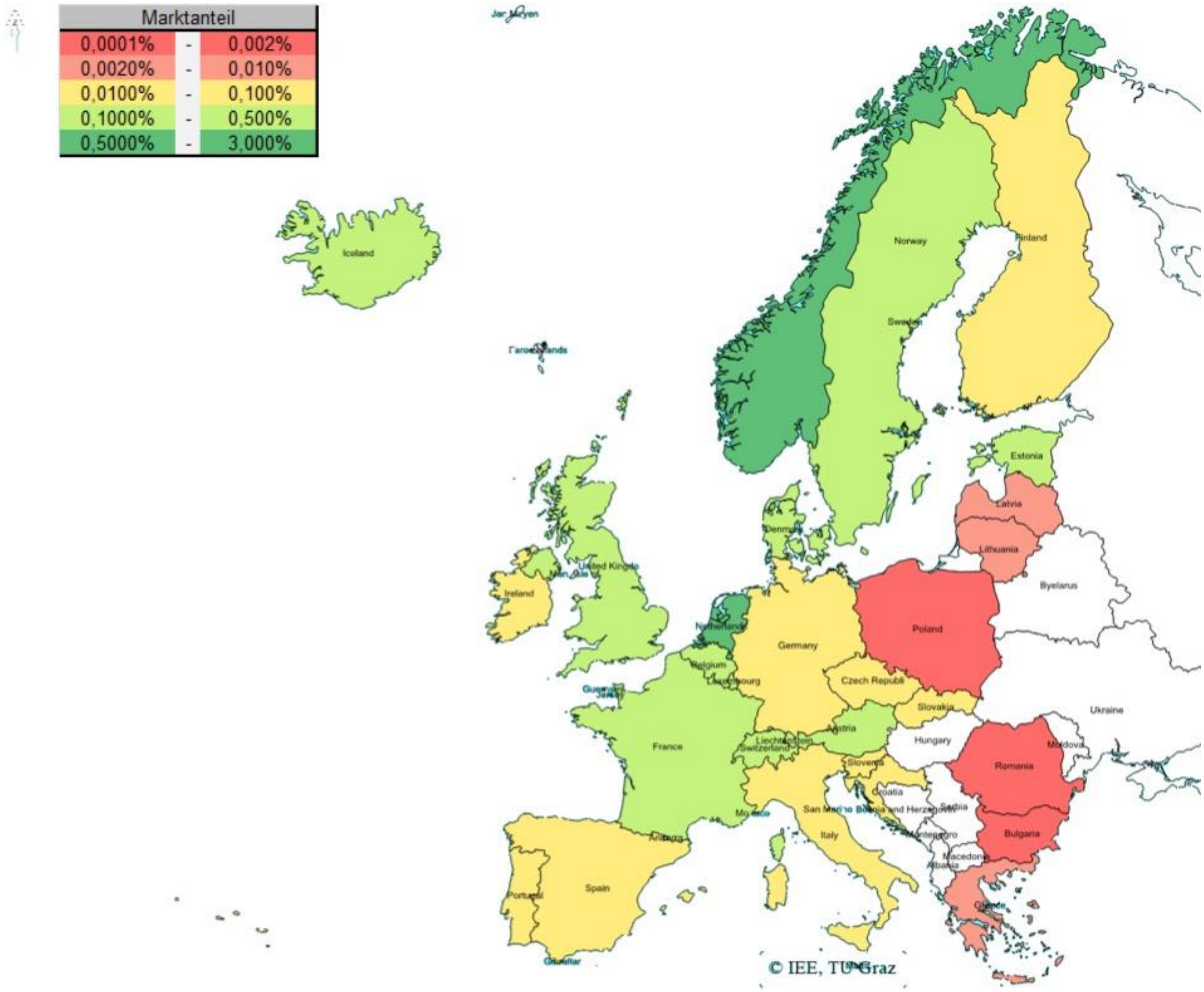

Figure 9.5 Graphical representation of the e-mobility shares in Europe

Summing up Figure 9.6 shows the cumulative development of EV in Europe between the year 2011 and 2015. In 2015 there have been already about 373.444 EV on the road in Europe, which is compared to the overall number of licensed cars still a small number, but marks the starting point for the future development of e-mobility in Europe

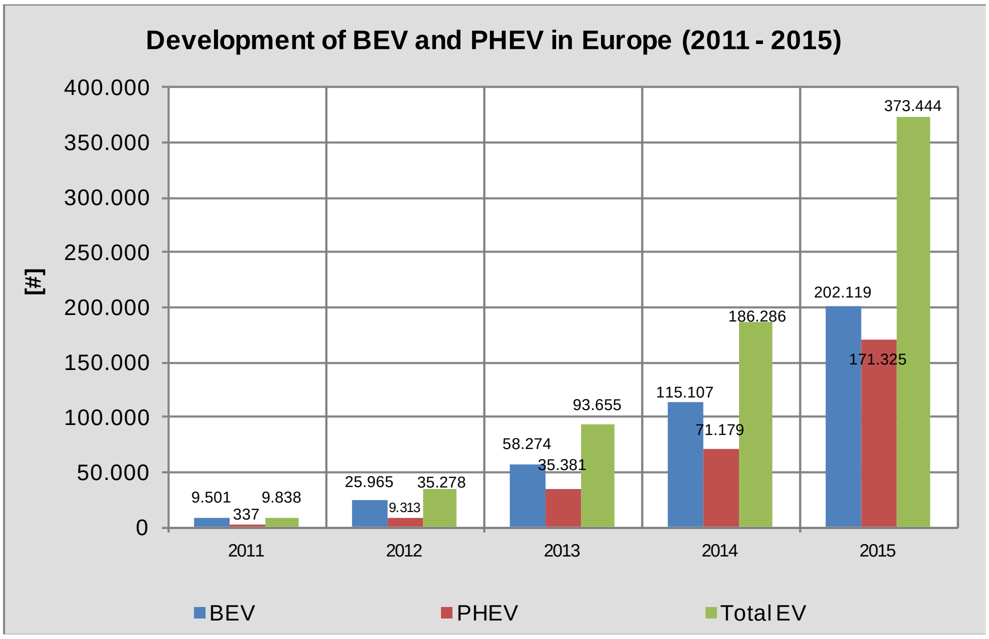

Figure 9.6 Development of EV in Europe 2011-2015

4 Scenarios for the Development of E-Mobility in Europe

Based on the investigation of the actual situation in Europe presented in chapter 0, this chapter deals with the future perspectives of e-mobility in Europe. A country based overall scenario for whole Europe does not exist so far in the literature and in order to adjust the developed scenarios, they are oriented on the global scenario from the IEA (see Figure 9.7) which includes also a path pointing in the direction of the goals of the afore mentioned Paris Declaration.

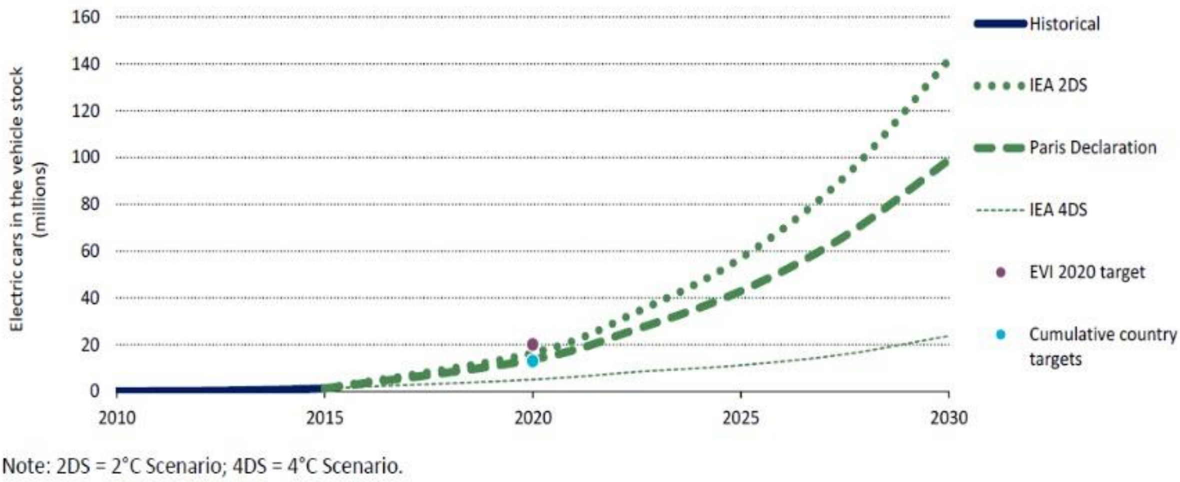

Figure 9.7 Global EV Scenario [6]

The IEA defined three different paths to 2030: The first scenario covers the needed EV in order to remain below 2°C global warming (100 million EVs), the second below 4°C (23 million EVs) and the third scenario describes a path in direction of the goals of the Paris declaration (100 million EV). This global scenario from the IEA forms the basis for the European scenario and it can be seen, that approximately 31% of the global market corresponds to Europe. Figure 9.8 shows the e-mobility goals for Europe based on the IEA scenario.

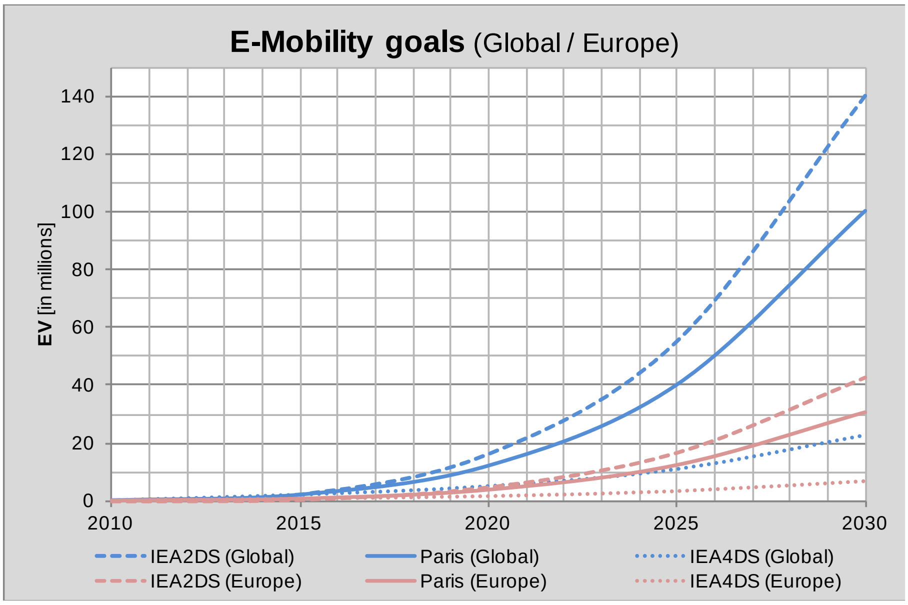

Figure 9.8: E-mobility goals for Europe based on the IEA scenario

Based on the derived boundary conditions for Europe up to the year 2030 three different scenarios have been generated: low, medium and high. The starting values have been taken from the presented investigations in chapter 0 and the development up to the year 2030 is based on the afore presented target values. Figure 9.7 shows the resulting values for Europe in the three different scenarios and shows also the percentage of the EVs in relation to the amount of totally running vehicles in 2030 (app. 382 million):

- Scenario LOW: In 2030 roughly 7 million EV will be seen in Europe corresponding to app. 1,8% of the European market
- Scenario MEDIUM: The target value for this scenario is 30 million EV in 2030 which corresponds to about 7,9% of the overall European market.
- Scenario HIGH: This scenario shows 43 million EV in Europe which equals 11,3% of the whole vehicle market.

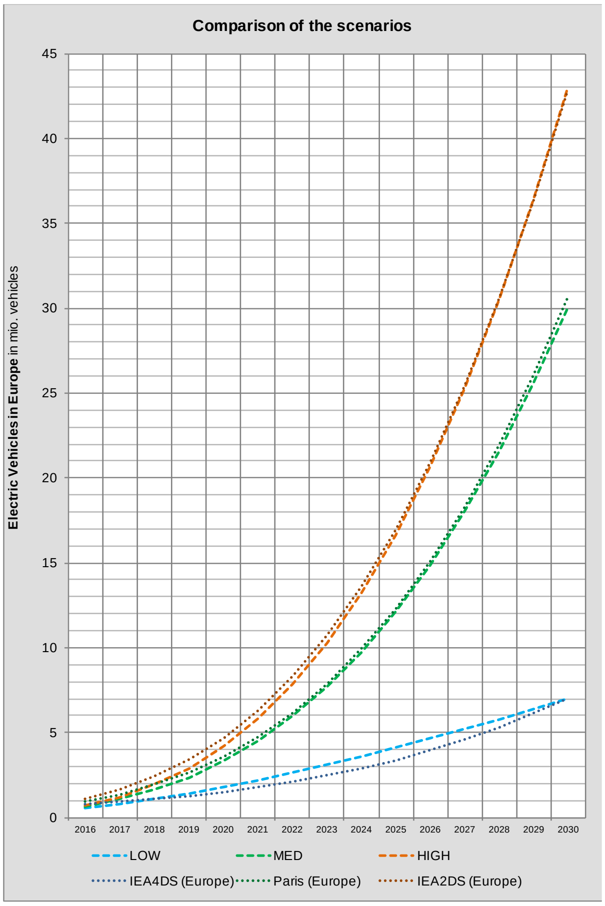

Figure 9.7 Overview of the derived scenarios

Regarding the energetic considerations some basic assumptions have been defined. Table 9.3 and Table 9.4 show an overview of present BEV and PHEV with their associated values. The tables also include the market share of the different models and based on those numbers a weighted average has been calculated, which is the basis for the following calculations.

Table 9.3 Data of present models BEV

Average values for BEV							
Ranking	Producer	Model	Distribution	technical data			
				electricity consumption	share driven electric	Battery capacity	Electric range
				kWh/100km	%	kWh	km
1	Renault	Zoe	27,35%	7,3	100	22	300
2	Nissan	Leaf	25,14%	16,9	100	27	160
3	Tesla	Model S	16,02%	16,0	100	85	530
4	Volkswagen	e-Golf	9,39%	12,7	100	24,2	190
5	BMW	i3	5,80%	11,0	100	33	300
6	Kia	Soul EV	4,97%	12,7	100	27	212
7	Mercedes	B250e	3,59%	14,0	100	28	200
8	Volkswagen	e-Up!	3,31%	13,4	100	18,7	140
9	Peugeot	iOn	2,49%	10,7	100	16	150
10	Citroen	C-Zero	1,93%	10,7	100	16	150
weighted average				**12,7**	**100%**	**34,3**	**271,4**
				kWh/100km	%	kWh	km

Table 9.4 Basic data for the PHEV reference car

Average values for PHEV									
				technical data					
Ranking	Producer	Model	Share	electricity consumption	fossil fuel consumption	share driven electric	Battery capacity	Electric range	Total range
				kWh/100km	l/100km	%	kWh	km	km
1	Mitsubishi	Outlander PHEV	24,81%	24,0	2	6%	12	50	800
2	Volkswagen	Golf GTE	12,92%	19,8	6	5%	9,9	50	939
3	Volkswagen	Passat GTE	11,89%	19,8	1,7	5%	9,9	50	939
4	Volvo	XC90 PHEV	11,63%	23,0	2,1	5%	9,2	40	850
5	Mercedes	C350e	9,82%	20,0	7	4%	6,2	31	850
6	Audi	A3 e-Tron	7,49%	18,3	1,7	5%	8,8	48	940
7	BMW	X5 40e	5,94%	29,0	10	4%	9	31	800
8	BMW	330e	5,43%	47,0	3,3	2%	10,8	23	1000
9	BMW	i3 Rex	5,17%	24,4	7	30%	22	90	300
10	BMW	225xe	4,91%	19,0	2	5%	7,6	40	800
weighted average				23,3	3,8	6%	10,4	45,8	840,7
				kWh/100km	l/100km	%	kWh	km	km

Based on the number of EV in the different scenarios and the definition of basic data for BEV and PHEV reference cars the needed electricity consumption has been calculated. In order to get a better overview of the value for the single countries, the calculated energy consumption for the EV is set in relation to the overall consumption of the regarded country. Figure 9.10 shows the results of the calculations and shows the share of electricity for EVs in relation to the total consumption per country for the three different scenarios. Based on the initial situation of the regarded countries the development is very different.

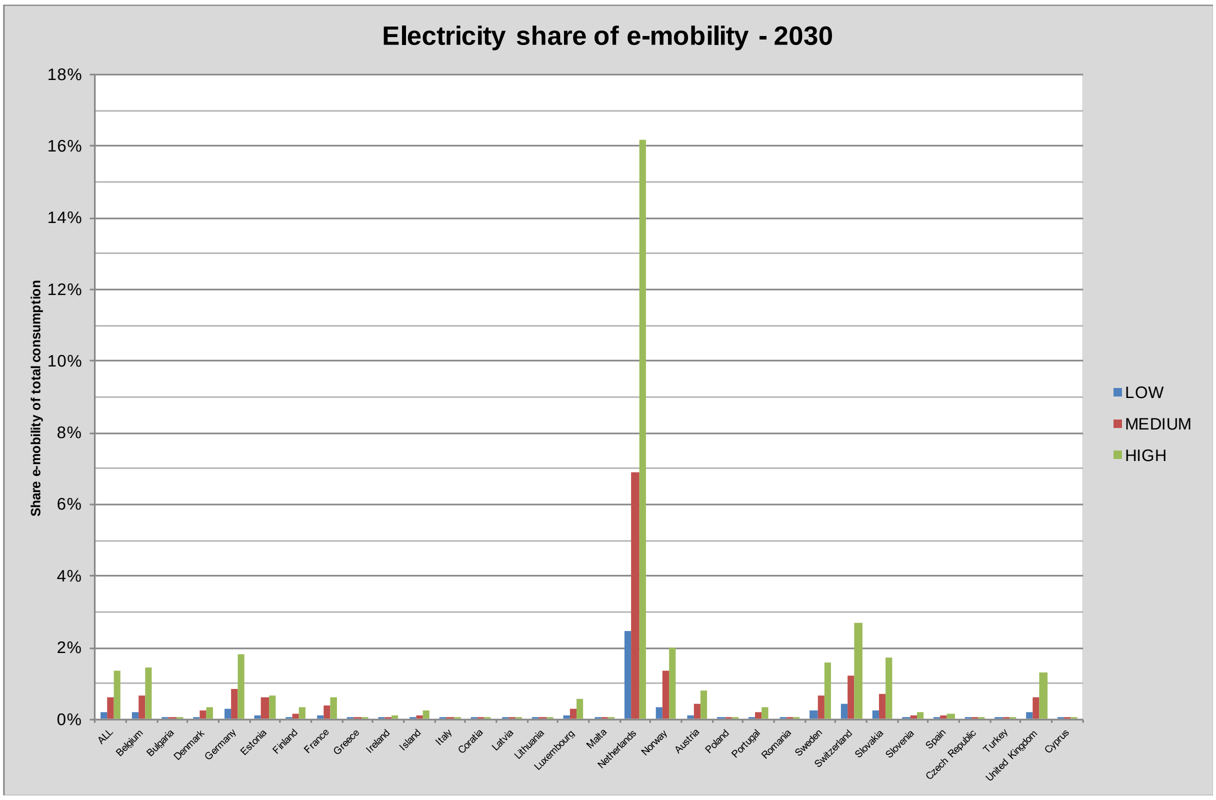

Figure 9.10 Share of electricity for e-mobility compared to total electricity consumption in 2030

Due to the fact, that EV hold already a prominent position in the Netherlands and it has been assumed that the Netherlands will follow this encouraged path also in the future.

5 Promoting Measures for E-Mobility

One key aspect for the future development of e-mobility concerns barriers and promoting measures. Within this work all European countries have been analysed regarding the status and future targets for e-mobility. A further aspect dealt with existing promotional measures as well as barriers in the different countries

Table 9.5 gives a summary of the different supporting measures, which exist in the different European countries at the moment.

Table 9.5 Overview of promotional activities for e-mobility

Category	**Description**
Support for the acquisition of vehicles	- Bonus in different heights - Saving of value-added tax - Often differences between BEV PHEV - BEV support often higher - Support often capped with list price - Scaling according CO_2 emission - Sharing of support between national an federal level
Cost of permission	- No cost for both BEV and PHEV - Sometimes just BEV exempt from permission cost - Reduction of permission cost - Scaling of permission cost according CO_2 emissions
Taxes on cars	Private consumer - no car tax for BEV - sometimes time limit for exception (5-10a) - Reduction for BEV - No engine based tax for BEV - No tax for BEV, 505 reduction for PHEV Companies - Tax deductibility for commercial vehicle - Scaling of tax according to CO_2 emission - No Tax for commercial vehicles - Other tax privileges
Local incentives	- Free parking or reserved parking lots - Usage of bus lanes - No road charges for towns - No road charges for highways
Infrastructural incentives	- Support for the erection of infrastructure - Public support for the building of fast battery chargers on main routes - Support for private chargers - Support for the installation of general charging points
Other incentives	- No import taxes or reduces import taxes

6 Conclusions and Outlook

In order to takle the future energy economic challenges – especially regarding the climate change – the mobility sector along with the energy sector will play an important role. Projections show, that the mobility sector is still growing, especially in the BRICS countries.

During the climate conference in Paris in 2015 (COP21) many countries agreed to fight against climate change and to present according measures. There are several options for the mobility sector like biofuels, hydrogen, but at the moment a strong tendency towards electro mobility can be seen. Electro mobility alone will not be the solution, but it offers the opportunity for reducing the carbon footprint in using renewable energies for producing the needed electricity. This paper gives a brief overview of the global situation and scenarios for EV and then focuses on the situation and development paths for Europe. The basic research comprised an in deep analysis for every single European country with a special focus regarding the situation of EV, supporting measures and the electricity demand. Due to limited available room within a paper the presentation of the results of every single country review is not possible, but the summarising figures are presented. Based on these analyses and already existing targets for e-mobility (e.g. IEA or Paris declaration) three development scenarios (low, medium, high) for the share of EV in the European countries have been built. Based on the present development state and the applied supporting measures in the different countries the scenarios show a distinguished development in the single countries. The range reaches from countries with an already remarkable share of EV and BEV like Netherlands and Norway to countries with very small amount of EV on the road like the Baltic states. The target values in the different scenarios for 2030 reach in the LOW-scenario from 7 million EV (app. 1,8% market share) and in the MEDIUM-scenario 30 million EV (app. 7,9% market share) to the HIGH-scenario with 43 million EV (app. 11,3% market share). Based on the derived scenarios a calculation of the needed additional electricity consumption for the EV has been done and the results have been presented in relation to the electricity consumption of every single regarded country. The last section of this paper presents a summary of the different promotional activities based on the single country analysis and lists further barriers which have to be overcome in order to reach the goals for e-mobility.

Summarising it can be stated that there are promising developments going on in the field of e-mobility in Europe but there are still some challenges (battery technology, range, loading infrastructure, vehicle cost, power management) to solve for the integration of a high amount of EV.

References

[1] Anderl M., Friedrich A., Haider S., et al: Austria´s National Inventory Report 2017. Wien, 2017
[2] UNFCCC. (2015). Paris Declaration on Electro-Mobility and Climate Change & Call to Action. Von Lima-Paris Action Agenda: http://www.unep.org/transport/EMOB
[3] BMWFW. (2016). Energy Status Austria 2016 – Development until 2014., www.bmwfw.gv.at, Vienna, 2016
[4] European Commission. (2011). White Book on Transport. ISBN 978-92-79-18269-3, Brussels.
[5] IEA. (2016). Global EV Outlook 2016. International Energy Agency.
[6] European-Alternative Fuels Observatory (EAFO), Homepage, www.eafo.eu, 2016
[7] European Automobile Manufacturers Association, www.acea.be, 2016