

# AN APPROACH TOWARDS PLANNING OF ELECTRIC VEHICLES CHARGING INFRASTRUCTURE BASED ON VEHICLE AND TRANSPORT STRUCTURE

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**Abstract** – Electrical vehicles are in a new phase of development and utilisation. It has been a long time before such initiatives have taken place. In the meantime the transport as a whole (vehicles, roads, traffic, etc.) has been significantly changed. As expected the main role in this process globally, and regionally is taken by the biggest economies and companies. Besides the environmental priorities, the nature of transport which does not recognise borders enforces smaller economies and countries to adopt their policies in this area, and take chances of the development. This seems to be very complex process with number of challenges. Some of them are very specific for different countries, and it is up to the local researchers to recognize and deal with them. This paper addresses the problem of the infrastructure, i.e. developing of a network of charging stations. Since there are number of specific technical aspects accompanying electric vehicles (types of vehicles, range, charging limitations, price, etc.), the research has started with analysis of the vehicle fleet, road network, and intensity of the traffic in different areas of Republic of Macedonia. This picture is compared with technical characteristics of emerging electric vehicles on the market. That was the way to recognize advantages and disadvantages of use of electric vehicles as substitution of some of the vehicles in the actual fleet. Possible development of use of electric vehicles in the country had to be estimated based on foreign experiences, and such policies in the country. As a result an approach towards development of network of charging stations in Republic of Macedonia has been defined. There is an obvious need this view to be widely presented and discussed with a possible outcome to serve as contribution to the challenges similar countries will face soon.

**Keywords:** ELECTRIC VEHICLES, CHARGING STATIONS, TRANSPORT, CHALLENGES

## 1. Introduction

Electric vehicles are one of the possible innovations capable of helping fighting challenges humanity is facing in the efforts of solving environmental issues.

Being aware that infrastructure is very important part of that process, this paper aims addressing these issues in Republic of Macedonia, especially towards possibilities of development of charging stations network, their types, possible locations, and partially their financing.

Parallel to the technical issues needed to be solved on the electrical vehicles, there is a need of intensive work on development of charging stations network. Since these two aspects are inseparable, development of charging equipment, charging stations, and their network basically depends of the same wide issues mentioning in the context of electrical vehicles. Hence, just as a reminder, common economic environment in which is expected development and use of electrical vehicles, will be mentioned.

Adopting and use of electrical vehicles is considered very limited without stimulation form external factors, like regulations on very limited pollution emission, increasing the fuel price, or financial incentives (Eppstein et al., 2011; Shafei et al., 2012; IEA, 2013). Between these factors, customer incentives have been identified as necessary in order to make use of electric vehicles massive on the market. (Hidrué et al., 2011; Eppstein et al., 2011).

As a consequence of this, the potential of fighting climate changes and use of the electrical vehicles is limited by mentality. Neo-classical economy point that governments policies should be employed to help improvement of such situation. (Rennings, 2000).

On the technical side of the problem, there are number of issues to be solved. Analyses done in this paper represent an effort to recognize the challenges, and make systematic review of the opportunities and limitations in the area of development of electric charging stations in a countries as Republic of Macedonia is.

Dealing in that direction, it is normal to start from the existing structure in the transport sector, i.e. road network, number and type of the vehicles, and intensity of traffic in separate regions of the

country. That will be followed by analysis of the processes of development of electric charging stations in the developed countries, and by presenting of the technical level of the charging stations, themselves. Towards the end, an effort to make comprehensive will be done with aim to identify possible ways of development of charging stations network in Republic of Macedonia. That could lead to identify separate positive and negative aspects of the process.

## 2. Road transport in Republic of Macedonia

The nature of transport as economy area dictates the need of each country to consider itself as a functional part of regional and global economy. Therefore, smaller countries, first of all, should be aware of global and regional developments, in this case, related to introducing of electrical vehicles in the transport. Understanding of such developments means taking the necessary steps towards avoiding blindness, and recognizing and taking the chances in all possible areas.

As important factors defining the strategy towards introducing vehicles in road transport, several key factors should be considered: road network, registered vehicles, type and intensity of traffic, type of industry, electrical network, legislation and standardization, research and education capacities, etc.

### 2.1 Road network

Fig. 1 shows road network in Republic of Macedonia. It shows, that besides main international roads, most of the network is concentrated close to the bigger cities/regions.

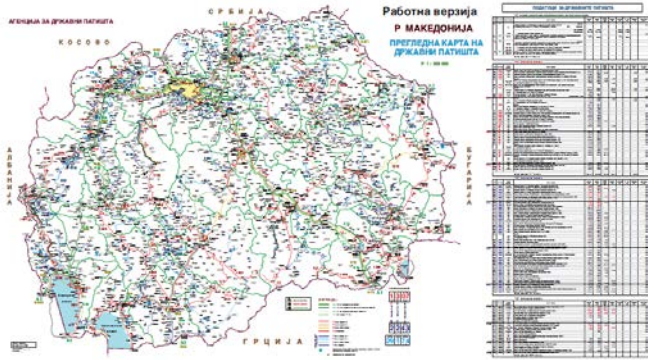


Fig. 1 Road network in Republic of Macedonia

Statistical report of State Statistical Office of Republic of Macedonia [8], gives an overview of road network in the country – tables T-1 and T-2.

T-1: Roads and road categories in km 2012	
TOTAL	14 038
of which asphalt and cobbled roads	8 308
ACCORDING TO ROAD CATEGORY	
Trunk	911
Regional	3 772
Local	9 355
International E-roads	553

T-2: Overview of local roads, situation 31.12.2012 in km		
	Total	Asphalt and cobbled roads
REPUBLIC OF MACEDONIA	9355	4 629
Skopje	551	335
Bitola	167	156
Ohrid	163	97
Shtip	150	39

2.2 Registered vehicles

Table T-3 shows review of registered vehicles in Republic of Macedonia and partially in some of bigger cities [8]

T-3: Registered motor vehicles in 2012			
	Motorcycles	Passenger cars	TOTAL
REPUBLIC OF MACEDONIA	8 473	301 761	350 762
Skopje	3 635	122 400	
Bitola	550	18 961	
Ohrid	573	8 910	
Shtip	237	8 489	

2.3 Road traffic

Main characteristics of road traffic, as one of the key information needed for planning, is shown in table T.4, and T.5, [8]

T-4: Length of E-road according year average daily traffic	
Road length, km	
	2010
Total	550.8
Less than 1000	-
1000 - 1999	13.5

2000 - 3999	195.8
4000 - 5999	194.2
6000 - 9999	41.6
10000 - 14999	105.7
15000 - 19999	-

T-5: Length and use of the roads, 2010						
	Length (km)	Kilometers passed (millions yearly)				
		Total	Motor cycles and three cycles	Passenger cars and light duty vehicles	Load vehicles	Buses
Total length	1724	178.4	2.2	143.5	27.1	5.6
Type of road						
All E-roads	550	63.1	0.1	55.2	6.1	1.7
Total non E-roads	1173	115.3	2.1	88.3	21.0	3.9
Highways	37	0.6	0	0.3	0.2	0.1
Other non E-roads	1136	114.7	2.1	88	2.08	3.8

The number of passengers in urban transport is shown in T.6, [8].

T-6: Number of passengers in towns in thousands, 2012	
Bitola	775
Skopje	68 270
Strumica	224

The table T.7 shows characteristics of Taxi transport [8].

T-7: Taxi transport, 2012	
Passenger cars, number	2 494
Kilometres travelled, in thousands	74 394
Urban and suburban transport	66 911
City to city transport	7 483
Passengers, in thousands	40 413

3. State of the art an expected development of charging stations network in Europe

Figure 2 shows number (in thousands) of charging stations in some European countries in 2012.

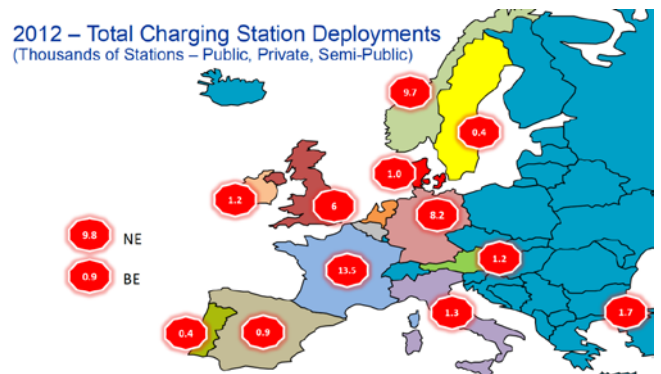


Fig. 2 Number of charging stations in some European countries in 2012 (in thousands)

The number of electric vehicles in the same period presented related to the number of inhabitants (in millions), and the number of public charging stations in Europe is shown on Table T.8.

T.8. Number of electric vehicles related to the number of inhabitants (in millions), and the number of public charging stations in Europe

II. Results in a single overview

The chart answers the knowledge questions and includes the following sections:

Financing indicates who finances the public charging infrastructure in the country:

- Grid operator
- Private
- Government

Role grid operator indicates the organisational role of the grid operator:

- Financing
- Connection to distribution network
- Other, such as a role as infra-provider or service provider

Interoperable indicates to what extent there is interoperability between charging stations of different providers:

- Wholly interoperable
- Interoperable between a few providers
- Not interoperable

Switching at station indicates to what extent it is possible to charge using electricity from an electricity company of choice:

- Switching at station is possible
- Switching at station is being investigated
- Switching at station is not possible

Country	Financing	Role grid operator	Interoperable	Switching at station	Number EV installations	Accessible number EV	Public stations per inhabitants	Number charging stations
1. Austria	H	f	X	X	126	1,047	65	536
2. Belgium	H	f	X	X	73	812	81	866
3. Denmark	H	f	X	X	240	1,368	123	681
4. Estonia	H	f	na	na	126	157	-	-
5. France	H	f	X	X	316	20,00	33	2,100
6. Germany	H	f	X	X	69	7,114	29	2,316
7. Iceland	H	f	checkmark	checkmark	52	234	141	662
8. Italy	H	f	checkmark	checkmark	56	3,315	10	640
9. Netherlands	H	f	checkmark	checkmark	162	9,266	152	3,720
10. Norway	H	f	checkmark	checkmark	2,757	13,626	657	4,029
11. Portugal	H	f	checkmark	checkmark	177	1,862	129	1,362
12. Sweden	H	f	X	X	265	2,568	49	416
13. Turkey	H	f	X	X	3	220	1	62
14. United Kingdom	H	f	X	X	129	8,183	62	3,901

Chapter IV provides an explanation of the information available per country.

Cumulative Public, Private, Semi-Public Charging Station Deployments – EMEA – 000s of Stations

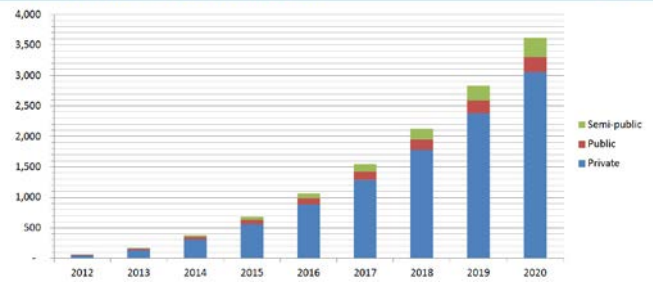


Fig. 4. Expected development of charging stations network in EMEA (Europe, Middle East, and Africa) region

Cumulative Charging Station Deployments – EMEA – 000s of stations

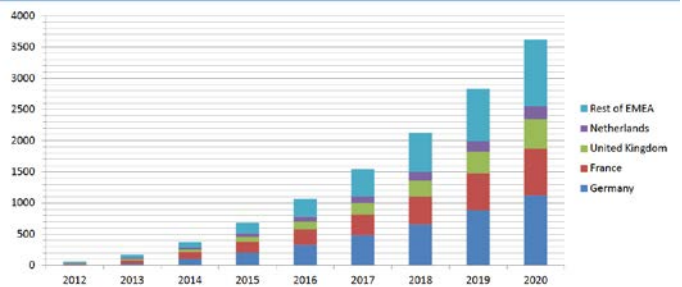


Fig. 5. Expected development of charging stations network in key countries in EMEA

Development of the charging stations network is dependable of one industry area which is under development – production of equipment for charging of electric vehicles - EVSE (Electric Vehicle Supply Equipment).

Figure 3 shows the chain containing all key factors in providing electric energy for electric vehicles.

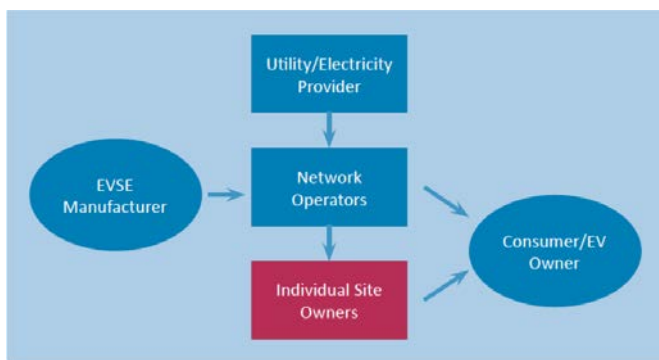


Fig. 3 Chain of supplying electric energy for electric vehicles

Figure 4 shows expected development of charging stations network in EMEA (Europe, Middle East, and Africa) region, i view point of owners, and Figure 5 shows the same view for the key countries in the same region.

It is widely expected that the number of charging stations in Germany pass the number of one million by 2020, and that number in EMEA region to be higher of 3.6 million.

Besides the number of technical issues which are not closed, like the standardization of charging stations and equipment, all involved, and especially, investors are facing additional business dilemmas. One of the most important is the business model, process forming, etc.

All mentioned makes estimation of profitability difficult, especially for nonresidential charging stations.

The efforts for the estimation start by these factors:

- On the income side:
  - o Existing strategies on forming on the price and business models in which the existing stations are operating at the moment
- On the costs side:
  - o The costs of the equipment and the installations
  - o The price of the electrical energy
  - o Prices of parking
  - o Government subsidies
  - o Price of the capital

Depending of the factors mentioned, the investors use different models in profitability analysis.

Different scenarios are used in the development of network of electric charging stations. Each scenario highly depends of strategies of development of use of electric vehicles. Until massive use of electric vehicles, main elements will be connected with the state policies in the areas of energy, economy and environment. The state support of the businesses in the area of development of charging stations will be very important, as well.

#### **4. Identification of main issues and analysis of possible ways of development of charging stations network in Republic of Macedonia**

Analysis of the process of introducing of electrical vehicles, and related to that, development of infrastructure of charging stations is pretty complex process due to lack of mass examples, and even a literature. The research activities and examples are restricted to separate regions, and due to that, different in core elements and content. Therefore it is not possible to come to a clear picture both for the situation and for the predictions. The situation with charging stations is even more complex compared to the electric vehicles, most of all due to the fact it is younger industry.

Based on the undertaken research activities, consultation with experts with years of experience in the area, and described characteristics of the road transport in Republic of Macedonia, several assumptions could be done in relation to the needs and possibilities in the process of introducing of electric vehicles in the country:

- The process of introduction of electric vehicles globally and in Europe is in the first phase of commercialization. In certain vehicle categories, first of all cars, global producers are offering more and more models attractive for different groups of customers.
- There are a number of technical and economic barriers defining that in foreseeable period the use of electric vehicles will be mostly limited to certain categories of vehicles (cars and partially light commercial vehicles), to certain zones (urban, suburban and closed campuses), and to a certain groups of users (municipalities, companies, individuals, etc.).
- Growth of the use of the electric vehicles in most developed economies (US and parts of EU) is expected to be in volume of 20-35% of passenger cars in the next 5-15 years. Use of such vehicles in Republic of Macedonia is expected to be with significantly lower intensity. Also, it is expected that the number of foreign electric vehicles travelling through Republic of Macedonia to be proportionally low. If the starting assumption is that such vehicles would arrive in the country with mostly empty batteries, the plans of building charging stations basically should include zones of crossing the borders, and zones of main crossings of E-roads and E-roads with other main roads. One could expect that the destinations of the foreign electric vehicles entering Republic of Macedonia country would be some of the neighboring countries, the Capital Skopje, some of bigger towns, and main touristic centers, as well.
- The development of the use of electric vehicles in Republic of Macedonia will be directly dependable of the national policy in the energy sector, but also of the policy in the environment protection, as well. The global and Europe experiences show that use of electrical vehicles is related to the urban and suburban areas, especially in the zones with progressive attitude towards environment protection. There a number of reasons that Republic of Macedonia follows such development. That means use of electric vehicles could be most intensive in the areas of the towns Skopje, Bitola, Tetovo, Shtip, Kumanovo, and so on. Maintaining the environmental advantages of the touristic regions is the reason of development of use of electric vehicles in the municipalities of Ohrid, Dojran, Mavrovo, and so on.
- Separate complexes – campuses could have specific attitude towards the environment. The examples could be health centers, education campuses, etc.

- Companies with fleets of passenger cars and small commercial vehicles with urban and suburban operations might be a separate group of users of electric vehicles.
- Taxi companies are one of the main possibilities of using electric vehicles in urban transport.
- Personal use of electric vehicles is very compatible for those families capable of having “second” car for mainly urban and suburban transport.
- There a possibilities of initiatives of production of electric vehicles, and more probably, conversion of the vehicles with engine with internal combustion into electric vehicles.

Main outcomes of the analysis in terms of the challenges and issues to be addressed towards development of the charging stations network in Republic of Macedonia could be grouped in this way:

- In environment of not fully standardized charging equipment, and taking into consideration state of the art and experiences available, and having in mind expected groups of users, there are three levels of ways of charging:
  - o Charging with simple plugs on standard network (220V) (Level 1). This level would be used in home conditions during long (normally by night) breaks of vehicles (mostly personal) use. Such method may be used by some companies having organized parking areas where company fleet of private cars of employees spend significant time.
  - o Charging by special charging equipment with higher power capacity (Laval 2). Their use is appropriate for public parking capacities, big markets, restaurants, and similar places where electric car users spend several hours.
  - o Fast charging stations (Level 3). Charging by this equipment is fast to certain level of batteries capacity and it can be used for additional charging for vehicles whose priority is shortening the time spent at the charging station. This equipment can be used on the main roads, on places like restaurants, existing petrol pumps, motels, hotels, etc. This level could be used as well on public parking, markets, etc. It is very important to have in mind that this type of charging equipment is very expensive and that it is still not clear their possible negative impact on the battery life.

Sustainability of the process of introducing and use of electrical vehicles with its whole complexity (production, conversion, purchase, service, development of charging stations network, etc.) is one of the main issues. All available experiences show that it is so far possible only with strong support and coordination from the government or municipalities. That shows there is a need country to take some of such known forms, or to develop and employ appropriate tools of support.

#### **5. Conclusion**

The dynamic nature of this moment of development of electric vehicles and their introduction in service poses significant risk to draw strong conclusions. Accepting it could lead to the following conclusions towards the process of development of network of charging stations in Republic of Macedonia.

It is obvious that the most influential aspect on development of the charging stations network will be the dynamic of introducing of electrical vehicles into service. At the same time, there is a opposite

influence, as well, i.e. charging stations infrastructure has a influence on decisions of buying electric vehicles. It is expected that in visible period of time, use of electric vehicles in Republic of Macedonia will be sporadic, until state takes strong measures in the frames of energy and environment policies.

Electric vehicles will be used, and charging stations network will be developed in urban and suburban areas. Touristic regions and other complexes could be other areas of use.

Government and municipalities fleets could include electric vehicles in some number. Different companies could lead or follow the example.

Electric power in foreseeable period will be used for part of the passenger cars, motorcycles and small commercial vehicles.

Standardisation of the charging equipment is significant precondition to the development of charging stations network.

There is a need of the same nature measures to support the charging stations businesses as those used to support production and market of electric vehicles.

According to the some predictions, the critical point in the development of charging stations network is the transition of dominantly state to dominantly private charging stations. In order to accelerate the process, there is a need of high number of private charging stations.

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