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How a City Prepares to e-Mobility in Terms of Public Charging Infrastructure

Case Study – The City of Zurich

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Abstract

This study has been developed on behalf of ewz, Zurich Municipal Electric Utility. The study estimates the charging infrastructure that will be necessary to meet the needs of the electric mobility in the city. In order to estimate the required charging stations, the number of electric vehicles (xEVs)[1] circulating in 2020 in Zurich have been defined taking into account the specific characteristics of the city. The study rated the city of Zurich more likely to introduce xEVs, compared to the Swiss average (100%): 2.5% in 2012 and 7.9% in 2020. These results have been applied to three scenarios that outline the number of xEVs in Switzerland. The expected market penetration for the city of Zurich results 16.3% in the maximum scenario, 8.1% in the medium scenario and 2.4% in the minimum scenario. In terms of charging infrastructure the following results arise: The maximum scenario expects 22,700 xEVs; 40,000 private power outlets; 1,500 public charging stations; and 10 public fast chargers. The medium scenario expects 11,200 xEVs; 20,000 private power outlets; 750 public charging stations; and 10 public fast chargers. The minimum scenario expects 3,300 xEVs; 6,000 private power outlets; 250 public charging stations; and 5 public fast chargers.

Keywords: Charging, infrastructure, city traffic, fast charging, mobility

[1] Electric Vehicles (xEVs), include BEVs (Battery Electric Vehicles), REEVs (Range Extended Electric Vehicles) and PHEVs (Plug-in Hybrid Electric Vehicles)

1 Introduction

Since 2011 most car manufacturers offer xEVs of second generation. Some information of the third and fourth generation is already available. Their expected competitiveness compared to conventional vehicles suggests that their market penetration will not be negligible.

ewz, Zurich Minicipal Electric Utility, strives to prepare the charging infrastructure for the city according to the demand of xEVs. On behalf of ewz, Protoscar conducted this study that is subdivided in three parts. This paper concerns the first part. The aim of the first part of the study was to estimate the required charging infrastructure that will cover the demand arising from the market penetration of xEVs in Zurich in 2020. The second part of the study analyses the business models of the public charging infrastructure, assessing the costs of the installation of the public charging stations. The third part potentially will concern the technical specifications of the public charging stations.

The study addresses the time frame that corresponds to the life of the vehicles of second generation and the market appearance of the third and fourth generations. These vehicles will have the same charging requirements. Therefore, if a 15-20 year lifetime is considered for the charging infrastructure, the charging stations that are installed today will be suitable for the fourth generation at the end of their life.

2 Charging Infrastructure Segmentation

The charging infrastructure is the set of all energy outlet points (charging points) where every xEV can be charged. A charging station is not a synonymous of charging point because more charging points can be integrated in one charging station.

It is important to highlight the 1:1 correspondence between charging points and xEVs: a charging station can be provided with more sockets, but if it is structured to simultaneously serve only one vehicle, it is considered a single charging point. If it is able to serve simultaneously two vehicles, it is equivalent to two charging points, etc.

For different charging needs different charging points are required. Therefore, the charging infrastructure has been categorized as follows:

- Regular Primary Infrastructure (I): for usual charging processes. Typically installed at home, at work and at parking places for fleets, i.e. where the car charges most of the needed energy. A charging station is considered corresponding to a power outlet. Each xEV needs a primary charging station.
- Occasional Secondary Infrastructure (II): for occasional charging processes. Typically in parking places on the street, at shopping malls etc. A charging station is considered corresponding to at least two power outlets. The number of secondary charging stations will be inferior to the number of cars.

This causes the total amount of charging stations (primary and secondary) to exceed the number of xEVs. The installation of additional charging stations, for instance public charging stations or fast chargers in strategic places, reduces uncertainty related to the range by offering supplementary charging possibilities. Initially, this charging infrastructure will facilitate the market introduction of xEVs by exercising a positive psychological effect reducing range anxiety and offering exclusive parking places for xEV-drivers.

The quantification of the charging points is done by subdividing the infrastructure in four main categories:

- sleep&charge: for regular charging processes. Typically installed at home, i.e. where the car charges most of the needed energy.
- work&charge: mainly for regular charging processes. For example, employees' cars or fleets that charge exploiting solar energy from a photovoltaic plant at work.
- shop&charge: for occasional charging processes in public locations, i.e. on streets, at railway stations, restaurant.
- coffee&charge: mainly occasional fast charging processes, e.g. motorway, gas stations or other accessible locations.

The classification was made according to the charging power (normal charging/accelerated, i.e. up to 11 kW, or fast, i.e. greater than 20kW) to the place of installation, the frequency of use (regular or occasional) and property (public or private).

Regular (Primary) Infrastructure			
Home	Private*	sleep&charge	Private garage or parking lot
Work	Private	work&charge	Garage/Parking lot at work (commuters)
Fleets	Private	work&charge	Garage/Parking lot for fleets (firms)
Streets 1	Public	sleep&charge	Garage/Parking lot for vehicles without private garage e.g. blue signed zone
Public Authorities	Public	work&charge	Garage or parking lot for fleets for public authorities
Occasional (Secondary) Infrastructure			
Firms	Private	shop&charge	Garage/Parking lot for (clients/guests) e.g. Hotels, restaurants, shopping centre
Streets 2	Public	shop&charge	Garage/Parking lot on the street e.g. white and blue signed zone
Fast Charging			
FC Fleets	Private	coffee&charge	Fast Charging for feelts
FC Parking1	Private	coffee&charge	Fast Charging e.g. Gas stations and other firms
FC Parking2	Public	coffee&charge	Fast Charging on the streets

* Refers to investment

Figure 1: Segments of the different charging points

3 Methodology

In order to identify the number of charging points needed to meet the needs of the xEVs in 2020, it is necessary to estimate the number of xEVs. The following steps have been undertaken to estimate the required charging stations in the city of Zurich.

3.1 Number of xEVs in Zurich

Three scenarios that investigated the Swiss xEV market penetration in 2020 serve as starting point. Through a preliminary strengths and weaknesses analysis of the introduction of xEVs in Zurich, relevant impact factors have been identified: inclination towards innovation, education level, development of industry and research institutes, past experiences in e-mobility, presence of a charging infrastructure, importance of public transportation, commuting, car sharing, topography, climate, presence of a supportive legislation, policy trend, individual income, demographic changes and car ownership.

To define the deviation from the Swiss average a panel of experts has evaluated the impact factors. Following, the results have been applied to the three existent Swiss xEV market penetration scenarios in order to adapt them to the city of Zurich.

3.2 Charging Infrastructure of the City of Zurich for Each Segment

The amount of each type of charging station has been calculated, for the whole city as well as for each of the 12 districts of Zurich. The charging infrastructure demand and the placement of the different types of stations does not only depend on the number of xEVs but also on other parameters, e.g. statistics regarding households, parking places, commuter flows, etc. which have been carefully analyzed. The statistical data has been extracted from different references as the Microzensus [3], statistics of the city of Zurich [7] and from the federal office of statistics [4].

4 Quantification of xEVs in the City of Zurich

The basic scenarios to estimate the market penetration of xEVs in Zurich result from the following three different sources that examine the xEV Swiss market in 2020:

- scenario MAX corresponds to the Alpiq Vision2020 [1]: 15% of all vehicles will have a plug in 2020;
- scenario MID is the basis vision of ewz [6]: 7.4% of all vehicles will have a plug in 2020;
- scenario MIN is based on the BFE's[2] study [2]: 2.2% of all vehicles will have a plug in 2020.

Applying the method explained in Chapter 3 the main findings about the factors with a significant impact on e-mobility in the city of Zurich are:

- Politics can actively contribute to the introduction of e-mobility;
- Some psychographic qualities of the population of Zurich could be a great prerequisite for the adoption of e-mobility;
- Public transport and individual e-mobility are not competitors but can and should be organized in order to be complementary (i.e. e-car sharing);
- Commuters travelling by car constitute a considerable potential of substitution;
- Although the number of cars is decreasing, individual mobility will not disappear until 2020. E-mobility is the sensible solution for a high life quality (no noise and local emissions).

Compared to the Swiss average (100%) the city of Zurich has been rated to be more likely to the introduction of xEVs:

- 2.5% in 2012 and
- 7.9% in 2020

This confirms that in the next few years e-mobility can develop in a positive way for the city of Zurich, which could become a forerunner in this field in Switzerland. Therefore it is necessary to prepare and develop comprehensive strategies.

Table 1 shows the market penetration of the city of Zurich considering and applying the results of the impact factors to the three scenarios that outline the number of xEVs in Switzerland.

Table 1: Estimated number and market penetration of xEVs in the city of Zurich in 2020

Scenario	xEVs in Zurich in 2020
MAX	22,700 (16.3%)
MID	11,200 (8.1%)
MIN	3,300 (2.4%)

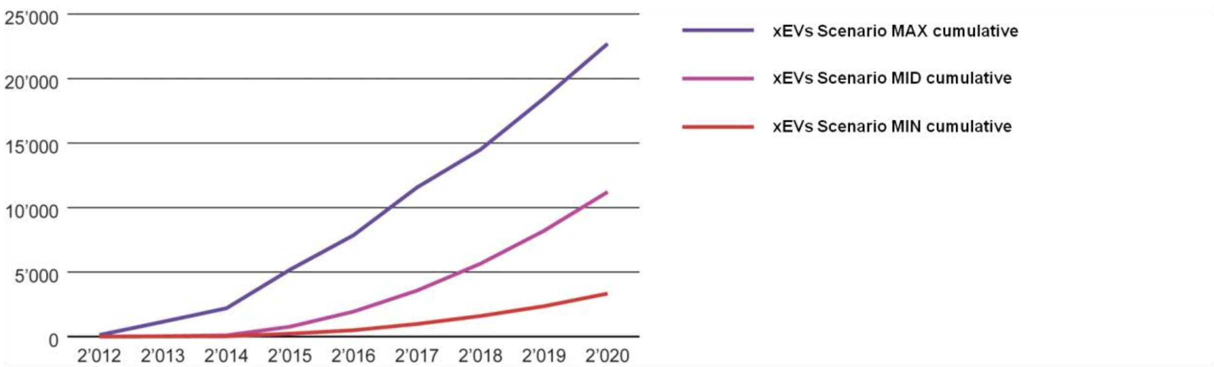

Figure 2: Estimated electric vehicles' growth in the city of Zurich

[2] BFE Bundesamt für Energie, the Swiss Federal Office of Energy (SFOE)

5 Quantification of the Charging Points in the City of Zurich

In general, the amount of charging points, must comply with the following conditions: 1) the total number of charging points must exceed the number of xEVs since it is the sum of the regular charging points (1:1 to the number of xEVs) and the occasional charging points;
2) the regular charging points must be installed together with the growth of the number of xEVs;
3) in order to foster the market penetration of xEV, the occasional charging point must temporally precede the arrival of these vehicles on the market.
The amount of charging points is proportional to the number of xEVs, therefore it also depends on time, given that the amount of vehicles varies from year to year.

As explained in Chapter 3 this dependence can be expressed as:

$$Q_i(t) = K_i N(t) \qquad (1)$$

N is the number of xEVs and Q_i is the amount of charging points of the segment i. K_i varies for each segment:

$$K_i = f_i(X_1, X_2, \cdots X_n, t) \qquad (2)$$

K depends on several variables X:

- Statistical data of the city of Zurich [7]
- National statistical data, when no statistical data of the city was available [4]
- Assumptions introduced by Protoscar

The following table shows the cumulative values of the charging points identified for each segment in the three scenarios in 2020.

Table 2: Each segment's number of charging points in 2020

2020	Private						Public			
	Home	Work	Fleets	Firms	FC Fleets	FC Parking1	Streets 1	Streets 2	Public Authorities	FC Parking 2
MIN	2'700	1'560	1'240	320	5	15	300	150	30	5
MID	9'080	5'250	4'190	1'080	15	20	1'010	490	100	10
MAX	18'250	10'630	8'680	2'190	50	30	2'000	1'010	200	10

Home: Private garage/parking lot
Work: Workplace
Fleets: Parking lots for fleets
Firms: Parking for guest/clients
FC Fleets: Fast Charging for fleets
FC Parking1: Fast Charging e.g. Petrolstation
Streets 1: Primary Infrastructure Parking for vehicles without private garage e.g. Blue signed parkings
Streets 2: Secondary Infrastructure Parking lots on the streets e.g. White and blue signed parkings
Public Authorities: Parking lots for fleets of public authorities
FC Parking2: Fast charging on the streets

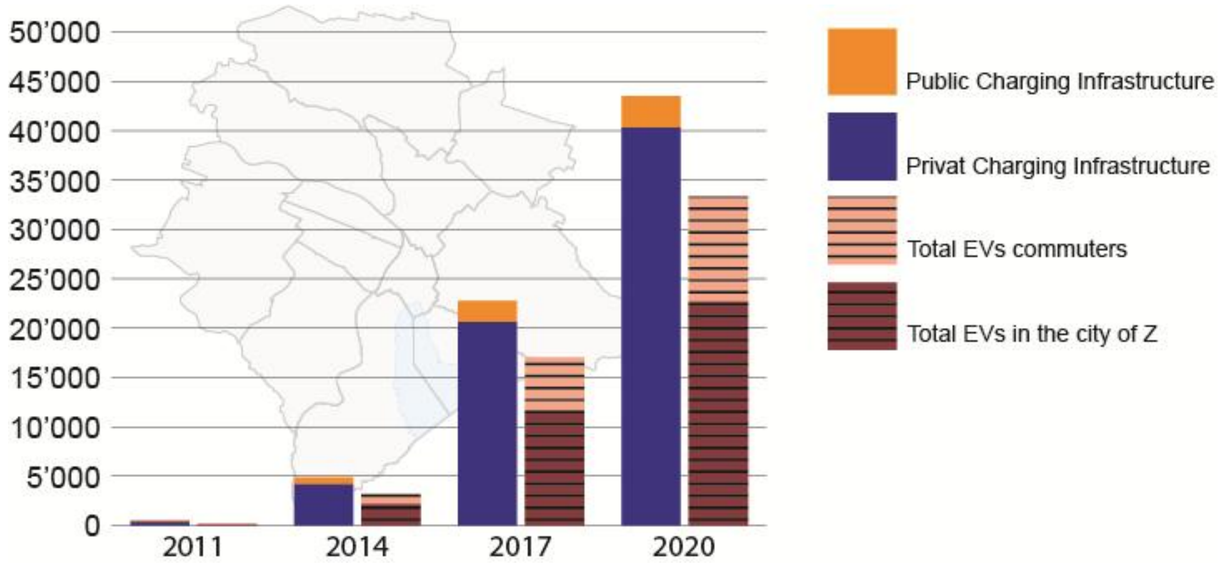

Figure 3: Comparison of public and private charging points and xEVs

In Figure 3 the numbers of the estimated xEVs and the needed charging points are compared. The amount of charging points exceeds the number of xEVs because a part of the charging infrastructure is complementary.

6 Conclusions

The main results for each scenario regarding the charging stations that will be necessary in 2020 to meet the needs of the electric mobility in the city of Zurich are displays in the following boxes:

Scenario MAX
approx. 22,700 xEVs (4,000 EV and 18,700 PHEV)

approx. **40,000** private power outlets allocated as follows:

18,000 in garages (I)
10,000 power outlets for commuter (place of work) (I)
8,500 power outlets for fleets (I)

3,200 public power outlets (only approx. 8% of the total) – approx. 1,500 public charging stations on the streets (I and II)

10 public fast charging stations installed in strategic places (II)

Scenario MID
approx. 11,200 xEVs (1,200 EV and 10,000 PHEV)

approx. **20,000** private power outlets allocated as follows:

9,000 in garages (I)
5,000 power outlets for commuter (place of work) (I)
4,000 power outlets for fleets (I)

1,500 public power outlets (only approx. 8% of the total) – approx. 750 public charging stations on the streets (I and II)

10 public fast charging stations installed in strategic places (II)

Scenario MIN
approx. 3,300 xEVs (300 EV and 3,000 PHEV)

Approx. **6'000** private power outlets allocated as follows:

2,700 in garages (I)
1,500 power outlets for commuter (place of work) (I)
1,200 power outlets for fleets (I)

500 public power outlets (only approx. 8% of the total) – approx. 250 public charging stations on the streets (I and II)

5 public fast charging stations installed in strategic places (II)

It is recommended to prepare the infrastructure according to scenario MID. In order to establish an appropriate infrastructure and since the installation of the charging points needs to follow the number of xEVs circulating on the streets, it is suited to confirm the numbers of registered vehicles after a few years.
Only the results of the first part of the research are delivered in this paper. However, the study continues in a second part that addresses the financial aspects of the public charging infrastructure. The focus is on assessing the costs of installing the public charging stations. Also the possible savings resulting from a suitable early planning of the charging infrastructure for xEVs are evaluated in the second part.
The same procedure applies for other cities or regions that would like to prepare to the forthcoming electric mobility by installing public charging stations. In fact, the same procedure has been applied for establishing the needed charging stations in the Canton Ticino (Switzerland). Moreover, also synergies with other projects as EVite, the nationwide and public accessible fast charging network of Switzerland can be built.
For cities and municipalities it is very important to consider also all the technical specifications of the charging infrastructure, as well as access and possible payment systems, in order to integrate everything in an early developed plan.

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Protoscar SA is a Swiss company founded in 1987 with a wide experience in the field of xEVs. The unique experiences gained with the different projects and the decisive collaborations with internationally known partners – as the Fraunhofer Institut IAO – allow Protoscar not only to develop forward looking strategies and outstanding vehicle concepts, but also to support the market introduction of CleanCars and the communication activities of these technologies. Furthermore, the insights of other projects contributed to this study: the “Vision 2020”, developed with Alpiq, as well as the practical lessons learned with the Pilot Project in Mendrisio, VEL-1 (1994-2001) allow Protoscar a holistic approach.