Energy Policy 121 (2018) 35–47

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Assessment of public charging infrastructure push and pull rollout strategies: The case of the Netherlands

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ARTICLE INFO

Keywords:
EV (electric vehicle)
Charging infrastructure
Key performance indicators
Policy
Rollout strategy
Supply vs demand

ABSTRACT

Over recent years, numbers of electric vehicles (EVs) have shown a strong growth and sales are projected to continue to grow. For facilitating charging possibilities for EVs typically two rollout strategies have been applied; demand-driven and strategic rollout. This study focuses on determining the differences in performance metrics of the two rollout strategies by first defining key performance metrics. Thereafter, the root causes of performance differences between the two rollout strategies are investigated. This study analyzes charging data of 1,007,137 transactions on 1742 different CPs by use of 53,850 unique charging cards. This research concludes that demand-driven CPs outperform strategic CPs on weekly energy transfer and connection duration, while strategic CPs outperform their demand-driven counterparts on charging time ratio. Regarding users facilitated, there is a significant change in performance after massive EV-uptake. The root cause analysis shows effects of EV uptake and user type composition on the differences in performance metrics. This research concludes with implications for policy makers regarding an optimal portfolio of rollout strategies.

1. Introduction

Over recent years, numbers of electric vehicles (EVs) in the Netherlands have shown a strong growth, from 1,100 in January 2012 91,000 in April 2016 (RVO, 2016), and sales continue to grow (Schroten et al., 2015). With a total number of 8 million cars in the Netherlands in January 2015 (CBS, 2016), and governmental policy aimed at 1 million EVs in the Netherlands in 2025 (RVO, 2016), the growth potential of EVs in the Netherlands is high. For facilitating charging possibilities for these vehicles, numbers of public EV Charging Points (CPs) in the Netherlands have grown simultaneously from 1,250 in January 2012 to 7,844 in April 2016 (RVO, 2016), and are also expected to continue to grow. Not only will the demand for public EV charging infrastructure increase with the growth in EVs, around the world governmental policy is also aimed at a continued large scale rollout of public charging infrastructure (Benysek and Jarnut, 2012; Hoekstra and Steinbuch, 2014; Steen et al., 2015).

The public EV CP rollout by the national government started in 2009 and was aimed at overcoming the chicken-egg problem between EV sales and EV charging infrastructure. The national governmental policy until 2013 has been that local and regional governments could apply for a CP at EVnetNL (former Stichting E-laad) which managed the application, selection and installation procedure CPs. The national government subsidized the installation (Agentschap, 2013).

Two rollout strategies were used. In the first strategy, the applications were based upon a request by an electric vehicle driver for a CP near to home, a so called ‘demand-driven’ CP. In the second strategy, the applications were based upon a decision by a local or regional government to place a CP near public facilities (e.g. governmental buildings, shopping malls) or on strategic locations where (occasional) use was expected (e.g. sporting grounds and leisure locations), a so called ‘strategic’ CP.

A demand-driven rollout suggests that the resulting CPs have at least one dedicated user and have a higher probability to be in a residential area. A strategic rollout suggests that the resulting CPs are used by a wider variety of users, that the use of certain CPs could be related to the opening times of nearby facilities, and that they might be in low-populated areas with a low demand for charging. This raises the question whether demand-driven CPs perform better than strategic CPs.

Research on public charging infrastructure planning and rollout has been performed since the uptake of EVs started around 2006–2008 (Dharmakeerthi et al., 2015; Uhrig et al., 2015). Most studies focus on

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https://doi.org/10.1016/j.enpol.2018.06.011
Received 9 June 2017; Received in revised form 9 February 2018; Accepted 8 June 2018

the location of charging infrastructure in relation to expected users and their charging patterns (Bessler and Grønbæk, 2012; Bunzeck et al., 2014; Philipsen et al., 2015; Robinson et al., 2013; Xi et al., 2013). The assessment of the different charging infrastructure rollout strategies in relation to their performance has become an important aspect to urban planning and policy studies (Helmus and van den Hoed, 2016; Madina et al., 2015; Paffumi et al., 2015a). So far, most studies tend to focus on only the early phase of rollout (100–500 CPs) (Xiong et al., 2015), use a limited database in both charging transaction quantity and time-scale (Khoo et al., 2014; Morrissey et al., 2016; Xydas et al., 2016b) or simulate EV charging data based on indirect data sources such as GPS sensors of non EVs (Andrenacci et al., 2016; De Gennaro et al., 2014; Kelly et al., 2012).

This study focuses on determining the differences in performance metrics of the two much used rollout strategies: demand-driven and strategic. Moreover, to advance understanding of charging infrastructure performance, the root causes of performance differences between the two rollout strategies are investigated. The paper aims to contribute to understanding whether, when and under which circumstances one of the two rollout strategies is more successful in deployment of charging infrastructure. It uses a real-world database of more than 1 million charging transactions, which to the best of our knowledge is a significant larger set than found in previous literature on public charging infrastructure (Kara et al., 2015; Morrissey et al., 2016; Xydas et al., 2016a).

2. Performance measurement of charging infrastructure

An important condition for evaluating the different rollout strategies is a clear definition on the performance of CPs; what are logical indicators for CPs to be evaluated on. Since the start of EV adoption research has focused on the potential impact and risks of electric vehicles on the electricity grid under circumstances of large EV adoption (De Gennaro et al., 2014; Kelly et al., 2012; Xydas et al., 2016b). There is limited literature on Charging Infrastructure (CI) performance assessment. A number of studies have looked at the connection of stakeholders directly concerned with decision making for CI rollout to performance (Helmus and van den Hoed, 2016; Madina et al., 2016; Saarenpää et al., 2013).

Madina et al. (2016) provide an analysis of the economic feasibility of international CI business models from different roles in the EV-ecosystem. In this research, the yearly transaction volume (in kWh) was indicated as main driver for economic feasible business models, next to additional pricing options. Moreover, the transaction volume is directly related to the number of km's facilitated and is therewith linked to clean air policy objectives. In this research the *weekly transaction volume* is seen as an indicator for the effectiveness of use of a CP.

Helmus and van den Hoed (2016) drafted performance measures performance measures in terms of (1) effectiveness: does charging infrastructure facilitate EV adoption, and (2) efficiency: are CPs used in an efficient manner. To compare the performance of demand-driven and strategic CPs this research considers the performance indicators of policy makers at municipalities and Charging Point Operators (CPO) (Helmus and van den Hoed, 2016). From this research two performance indicators were used; (1) the number of unique users and (2) the connection duration.

The *number of unique users* is an indicator for the diversity in users by which a CP is used and can be related to the facilitative role of municipalities. While this is a valid performance metric, a limitation is that the total number of sessions per user on a CP is not considered. From this perspective, a strategic CP with 8 unique users and a total of 12 sessions outperforms a demand-driven CP with 2 users and 20 sessions.

The *connection duration* refers to the duration in which a vehicle is connected to the CP and can be regarded as a performance measure of the intensity of use. Depending on the local business model, the connection duration could also be part of the revenue model as connection tariff for CPOs (Madina et al., 2015; Wardle et al., 2015).

Table 1
Charging point data structure.

Performance indicator	Measured achievement
Weekly number of unique users	Facilitation of charging infrastructure
Weekly connection duration per charging point	Intensity in use of charging infrastructure
Weekly amount of kWh charged per charging point	Effective use of charging infrastructure
Weekly charging time ration	Efficient use of charging infrastructure

The *charging time ratio* is the ratio between total charging time and total connection time on a weekly basis and varies between 0 and 1. It is seen as a metric for the efficient use of a CP and the higher the value the more efficient use is made of the CP. This metric includes effects of charging behavior such as (long) parking without charging or short fulltime charging sessions. This ratio, also known as load flexibility, is used in the aforementioned optimization studies as basis for the optimization algorithms (Schuller et al., 2015), such as time dependent rescheduling of energy transfer from peak demand to lower demand hours. In this case a lower ratio implies more flexibility and optimization potential. The complexity of load flexibility in combination with time of day is not considered in this research for the purpose of this paper is to compare the performance of two rollout strategies rather than defining the optimization potential. Table 1 displays an overview of performance indicators.

2.1. Hypotheses

The following hypothesis were setup and tested with the available dataset. (H1) Strategic CPs are expected to outperform demand-driven CPs on the user facilitation. Demand-driven CPs are installed due to one or more requests and are expected to start with one user weekly user from installation date with a potential increase over time, whereas strategic CPs could start a many levels and develop in any direction over time depending on the total EV population.

Regarding the total weekly connection time the following hypothesis was developed; (H2) Demand-driven CPs are expected to display longer weekly connection times than the strategic CPs. This hypothesis is based on the idea that different charging strategies occur at different locations, such as home charging strategies with overnight charging and random charging for long and short parking times.

The third hypothesis states; (H3) Demand-driven CPs are expected to perform better on weekly energy transfer than strategic CPs. This hypothesis is based on the suggestion that demand-driven CPs will have at least one regular user charging with its use pattern, while strategic CPs are assumed to display a combination of irregular use patterns (De Gennaro et al., 2015; Paffumi et al., 2015a). Moreover, the demand-driven locations, particularly home locations are expected to be at an end of trip location or end of day location, while strategic CPs could be at any position in the daily travel activities of an EV (Nie and Ghamami, 2013; Sathaye and Kelley, 2013).

The last hypothesis is on the efficiency of both types of CPs; (H4) Strategic CPs are expected to outperform demand-driven CPs better on efficiency with higher charging time rations. This hypothesis is based on outcomes of research on optimization potential in residential and non-residential areas (De Gennaro et al., 2015; Kara et al., 2015).

3. Method

At the start of this research data on charge sessions and locations were gathered from CPO EVnetNL (EVNETNL, 2016). The data was