Methods for Efficient Charging Infrastructure Placement

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Abstract—**Without comprehensive spatial coverage and demand-appropriate distribution of charging points, potential users of electric vehicles have little incentive to make the jump from conventional to battery-electric motor vehicles.**

Whether charging infrastructure expansion is effective will be determined by future demand, the quality of the coordination between stakeholders and exploitation of potential synergies between public, semi-public and private charging infrastructure.

Today, charging infrastructure planning must include all interested parties, many of whom had not been considered until recently. These include municipalities, public works departments, distribution system operators, transit authorities, car-sharing companies, charging infrastructure operators, supermarket chains, and landlords.

Because any one stakeholder can now play multiple roles, the traditional channels and directions of communication in the energy industry will change.

Charging infrastructure must meet conflicting criteria. Decision-makers need a tool or suite of tools that helps them to balance these competing criteria. Any such tool must make electromobility development potential apparent, deliver reliable estimates of future demand and assist in coordinating planning, implementation and operation of charging infrastructure.

So far, most planning tools do not include the full spectrum of charging powers available between 2.7 kW and 350 kW, have not considered mid- and long-term time horizons for infrastructure development, and do not have the ability to directly include all the stakeholders in the planning process. Further, they typically do not integrate real-time data from monitoring of existing charging stations, a requirement for any demand-oriented infrastructure planning.

Successful integration and use of charging points also require coordination with on-site implementers, as well as consideration of specific site conditions and information about independent activity in semi-public and private spaces not traditionally gathered by governments and planners.

We introduce a set of quantitative and qualitative methods for producing robust planning guidance based on our experience in the German state of Brandenburg.

I. Introduction

The current discussion surrounding electromobility has been dominated by insufficient availability of charging infrastructure. Without comprehensive spatial coverage and demand-appropriate distribution of charging points, potential users of electric vehicles have little incentive to make the leap from conventional to battery-electric motor vehicles. For this reason, the strategic expansion of the charging network must be pushed at both the local and national levels. Currently, there are 10,700 publicly-accessible charging points at 4,730 charging stations [1]. The German government intends to fund an additional 100,000 public charging points through 2020, which is evidence that it has recognized the problem [1]. Good planning is nevertheless essential for success.

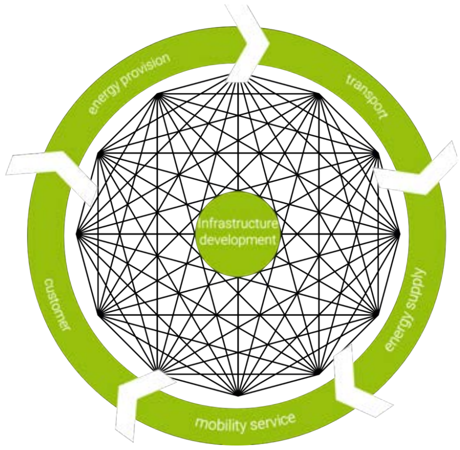

Figure 1. Schematic representation of the value chain components.

Effective communication and coordination between stakeholders in planning, approval, implementation and operations are important for optimal planning. Because stakeholders can play multiple roles (as both producers and consumers for example) and do not occupy a single position in the value chain, the traditional communication channels in the energy industry will change. The traditional value chain will be replaced with a *value cycle* having many cross-connections (Fig. 1). Charging infrastructure planning now includes all interested parties, many of whom had not been considered until recently. In RLI's view, this process requires a common platform where the electromobility development potential is apparent, the demand can be estimated and planning, implementation and operation of charging infrastructure are coordinated.

II. The State of the Art

According the German National Electromobility Platform (NPE), the readiness of the public to use electric motor vehicles can be increased through expansion of public charging infrastructure, a need now beginning to be addressed by the aforementioned 100,000 new public charging points [1]. Further, charging infrastructure is to be installed in semi-public and private spaces. To achieve comprehensive and demand-appropriate coverage, the NPE has stated that a distribution of charging services with 85 % in private, 10 % in semi-public and 5 % public spaces is required.

Currently, charging infrastructure planning is performed using project-specific methods and tools. These consider different parameters for assessing potential charging demand when placing charging points in public spaces.

For example, *STELLA*, developed at RWTH Aachen for the *SLAM* project (*Schnellladenetz für Achsen und Metropolen*, "fast charging network for axes and metropolitan areas") uses demand, traffic, infrastructure and electric system data [2][3]. As its name implies, this tool identifies optimal placements for fast-charging infrastructure.

Similar data are used by *Current*, the analysis model developed cooperatively by the German Aerospace Center (DLR) and the Karlsruhe Institute of Technology (KIT). It uses traffic data, vehicle data, vehicle usage profiles, demand data, infrastructure data and assumptions about charging behavior and infrastructure. *Current* is a component of the *LADEN 2020* ("Charging 2020") project. The project's goal is to plan charging infrastructure expansion through the year 2020 and describe corresponding implementation options [4].

These planning tools assess development potential using data and derive the required infrastructure expansion. Successful integration and use of charging points also require coordination with on-site implementers, as well as consideration of specific site conditions and independent activity in semi-public and private spaces. An example would be the installation of charging points in semi-public spaces such as shopping center parking garages, which will necessarily affect use of public infrastructure in the immediate vicinity. A plan based purely on statistical data cannot anticipate these potential conflicts (consider that 90 % of charging events are expected to occur in semi-public and private spaces). Therefore, the planning and coordination tool presented here does not leave the charging network planning to a single stakeholder group, but rather includes, using appropriate interfaces, decision-makers, implementers, and the general public in the process.

III. Motivation for the development of a dedicated charging infrastructure planning tool

Currently available planning tools do not differentiate between fast and standard charging points, do not consider mid- and long-term time horizons for infrastructure development, and do not have the ability to directly include different stakeholders in the planning process. Further, they cannot monitor existing charging stations, a requirement for demand-oriented infrastructure planning. Future planning tools must address these gaps.

Many parties have a stake in charging infrastructure development. These parties include but are not limited to municipalities, public works, distribution system operators, transit authorities, car-sharing companies, charging infrastructure operators, supermarket chains, and landlords.

Expansion of charging infrastructure is strongly influenced by future demand, coordination between stakeholders and potential synergies between public, semi-public and private charging infrastructure. Robust data can speed infrastructure expansion, so we are actively promoting cooperation with infrastructure operators and users and are supporting the development of new software to maximize data availability and improve communication between stakeholders.

IV. Use cases for a web-based planning and information platform

Participants in the planning process have access to different information about electromobility development potential and site conditions. The following use-cases and questions are considered:

- Supermarket operators would like to install charging infrastructure, but need an assessment of likely demand before doing so. The tool uses a set of social, economic and traffic engineering metrics to estimate future demand.
- Electrical system operators must know where charging demand is likely to be highest and result in high loads. Critical points identified by the planning tool can be considered during electrical network planning.
- Landlords want to prepare for charging infrastructure expansion in their existing buildings and new construction. To do this, they must understand socio-economic factors driving tenants to choose electric vehicles.
- Car-sharing services typically establish themselves in inner-city areas where parking space is disappearing or is restricted through user-pay parking management. Car-sharing operators want to know which car-sharing services are appropriate (for example, free-floating vs. stationary) in which areas and how these models can be supported by specific charging infrastructure placement strategies.

V. Methods

Charging infrastructure expansion requires consideration of coverage area, demand and other criteria such as emissions, interactions with public transit, shipping, carsharing and urban development plans (Fig. 2). These criteria can be in conflict. Motorists must have sufficient charging opportunities (availability), while the load factor (portion of total time the charging station is in use) must be also be high enough that the charging point operator has a reasonable expectation of return on its investment. Accordingly, both sufficient and demand-appropriate coverage over the service area are the focus. Given adequate data, air quality problems may also be addressed by identifying influential stakeholders in the area and determining opportunities for electrification of their fleets and facilities.

The first step of the development process ends with the installation of the charging infrastructure.

VI. Results

In a study conducted by RLI for the German state of Brandenburg, electromobility development potential was assessed using the analytic hierarchy process. The results showed that the potential was characterized by a distinct gradient leading from the commuter belt surrounding Berlin out to the regional growth centers and then finally to sparsely populated rural areas (Fig. 4). This analysis was used as the basis for the state's charging infrastructure planning.

The assessed electromobility development potential allowed us to estimate the future electric fleet size in the

- **Points of Interest (POI)** (incl. supermarkets, museums, schools, hardware stores, parking spaces, parking garages etc.)
- **Sociodemographics** (land use category, income, number of Green Party voters, average rents etc.)
- **Electrical system** (managed expansion through demand- oriented planning, etc.)
- **Type of charging infrastructure required** (overnight charging in residential neighborhood, 1-2 hours while shopping, going to the cinema or gym, 15 min while passing through)
- **Traffic flows** (loads, main arteries, etc.)

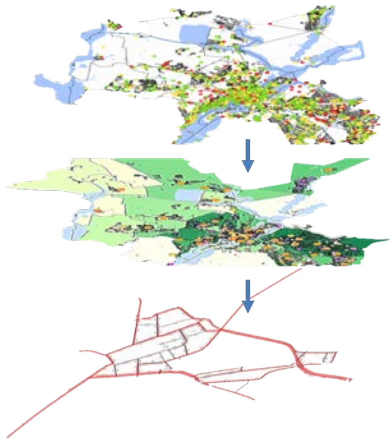

Figure 2. Types of information that should be considered in charging infrastructure planning.

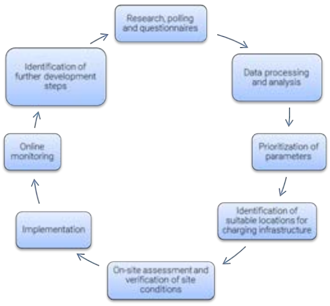

Figure 3. Schematic representation of the individual steps in placement of charging infrastructure.

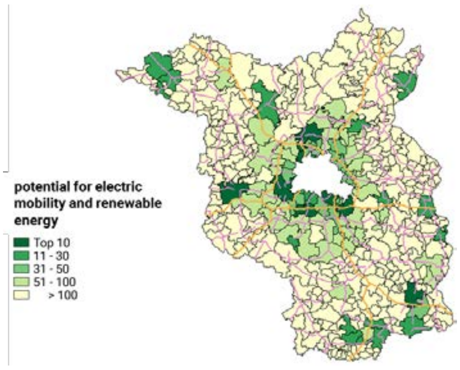

Figure 4. Visualization of AHP result for 418 municipalities in Brandenburg.

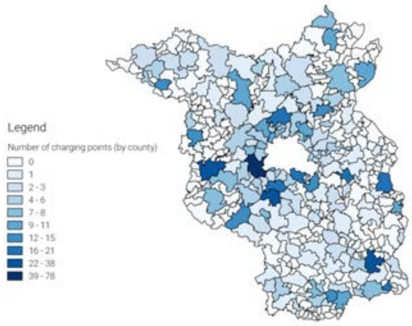

Figure 5. Computed distribution of standard charging points among municipalities in Brandenburg.

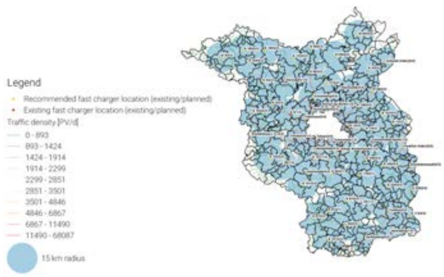

Figure 6. Draft plan for an initial fast charging infrastructure.

region, which was then used to appropriately distribute standard charging points between the individual municipalities (Fig. 5).

The resulting distribution is aimed at serving longer-term parkers (commuters at work, at home or at POIs such as shopping centers, sports facilities and museums). Long parking times justify the deployment of standard charging stations with low charging power. Long-distance travel with electric vehicles through rural areas requires fast charging stations, since motorists will not accept long waits while in transit. Deployment of fast-charging stations with at least 22 kW charging power was reserved for rural areas. The stations were placed in such a way as to limit the maximum distance from any point in Brandenburg to a fast charger to 15 km and thus enable long-distance travel in any direction in the state. According to the *Nahverkehrsservice Sachsen-Anhalt* (the regional transit authority of Saxony-Anhalt) this is the maximum distance consistent with *coverage security*. Using this limiting condition, we determined that 58 locations for fast charging stations were sufficient to ensure complete initial coverage (Fig. 6).

Next, a detailed charging infrastructure plan was drafted for the state capital, Potsdam, again employing socioeconomic, traffic and infrastructure characteristics. Points of Interest were also included in the analysis and helped guide the exact placement of charging points. Parking lots and garages, both above and below ground, were considered as candidate locations for charging infrastructure. The analysis

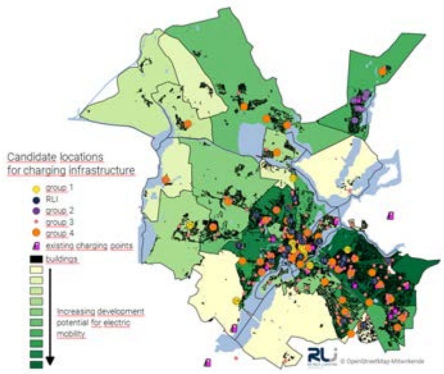

Figure 7. Evaluation of city districts for charging infrastructure development potential and placement of charging stations.

showed suitable locations in the inner city near frequently visited POIs, but also in desirable neighborhoods and new residential subdivisions (Fig. 7). A number of these suggested locations will now receive new charging infrastructure in the implementation phase of the state capital's strategy.

We found a strong correspondence between the locations identified using the methods described and the locations suggested in a poll conducted by the municipal government. The results were discussed with the municipal government, the municipal public works department and the service providers. As a result of these discussions, some site-specific conditions were identified and the locations selected were corrected accordingly.

VII. Outlook

The charging infrastructure planning process is normally limited to discrete zones. The planning methods presented here allow information exchange beyond regional boundaries, enabling individual municipalities, counties, states or countries to coordinate their efforts and meet the future needs of a fully-electrified transport system. Cooperation with other infrastructure operators and the easy access to a browser-based application could make comprehensive monitoring of the charging infrastructure expansion by all stakeholders possible and would provide a useful overview of local activity so that it may be considered in ongoing planning processes.

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