Agent-based Model Assessment of EV Charging Infrastructure in St. Gallen

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Agent-based Model Assessment of EV Charging Infrastructure in St. Gallen

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Outline

• Introduction

• Methodology

• Results and Discussion

• Conclusions
Introduction

• While today’s penetration of EVs is 0.3% in City of St. Gallen, City’s Energy Concept (EnK³) plans 50% penetration by 2050

• Technical and operational consequences for DSOs are unclear

• Goal: Quantify impact of EV penetration and EV owners’ behaviour on
  • Profitability
  • Impact on the grid of EV charging infrastructure in St. Gallen
Methodology
Digital Model of City of St. Gallen Developed

• Digital model integrates
  • geo-referenced data of population
  • buildings
  • energy infrastructure and
  • mobility infrastructure
Optimized Placement of EV Charging Infrastructure Using Agent-Based Mobility Simulations

- **Agent-Based Mobility Simulations**
  - Mobility simulations of weeklong period

- **Monte-Carlo Simulations**
  - EVs randomly distributed amongst population

- **Optimal Spatial Distribution of EV Public Chargers**
  - Spatial distribution of public EV chargers in City of St. Gallen optimized to maximize load factor
Agent-Based Models Account for Individual Characteristics

- Agent-based models of population and traffic used to simulate different scenarios
- Entire Swiss population is simulated
- Agent-based models detail individual characteristics and behaviors:
  - Price-driven
  - Comfort-driven (mostly charging at home)

Max Mustermann
Age: 31
Sex: Male
Home Municipality: Roggwil
Job Municipality: St. Gallen
Job Status: Full-time employed
Job Sector: Tertiary

<table>
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<td>St. Gallen</td>
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<td>inhabitants</td>
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<table>
<thead>
<tr>
<th>Daily Schedule</th>
<th>Time</th>
<th>Actions</th>
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</table>
|                | 08:13 – 09:00 | • Leave home  
                       |       | • Travel to work |
|                | 08:00 – 18:29 | • Work |
|                | 18.30 –19.05  | • Travel to sport activities |
|                | 18:30 – 22:00 | • Sport activities |
|                | 22:00 – 22:45  | • Travel home |
|                | 22:45 …        | • Home |
Simulation Framework Validated Against Available Measurements

- Predicted monthly charging cycles at 4 most widely used public EV charging stations show good agreement with 2017 data (0.3% EV penetration)
- Most used stations could be identified

![Map of Zürich with charging stations highlighted: Zil Garage, E-Taxi, Baldegger, EMPA]
Results
Revenues from Parking Fees Are Best Business Model To Operate EV Infrastructure

- Parking fees, based on prevailing market conditions, yield larger revenues for city’s utility than tariff based on power used to charge EV
- Revenues from parking fees are particularly impacted by behavior of customers
For Today’s EV Penetration Public Chargers Do Not Reach Break-Even

- Both simulations results and sgs measurements show underusage of publicly available chargers
- For City’s existing public EV chargers, load factor rapidly increases with increasing EV penetration
- For public chargers, break-even can be reached only with EV penetration exceeding 4%
- Considering also other charging possibilities in the city, time to break-even is 10 years at today’s EV penetration; it will be less than 3 years for EV penetration’s exceeding 2%
Usage of Specific EV Charging Stations Quantified

- Simulations quantify, over range of EV penetrations, usage of specific public EV chargers, as well as impacts of human behaviour and preferences
- More than 80% of charging stations will not recover their investment and maintenance costs
Privately-Owned Public Chargers Adversely Impact Local DSO

• 10 new, privately-owned EV public chargers, to be installed by 2020, will decrease usage of DSO’s existing 23 chargers, with 35% decrease in load factors for 2% EV penetration

• Competition from privately-owned EV public chargers decreases revenues by up to 35% at individual chargers.
Placements of Public Chargers That Optimize Usage Determined

- Optimized placement of public chargers that maximizes load factor determined for different EV penetrations

EV Penetration 20%
Required Number of Public Chargers Increases with EV Penetration

- Number of required public chargers obtained by both providing charging solutions to all EV owners and by maximizing infrastructure usage
- Number of required public chargers increases with EV penetration
- Required number of chargers depends on agents’ preferences and behaviors

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<th>EV Penetration [%]</th>
<th>Number of Required Public Chargers</th>
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<td>2</td>
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<tr>
<td>5</td>
<td>402</td>
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<td>10</td>
<td>552</td>
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Additional Energy Demand for EV Charging Quantified

- Additional energy demand of EV charging comes mainly from workplace and public charging.
- Sharp peaks of public charging may require use of energy management solutions as EV penetrations increase.
Different Behaviors of EV Owners Have Different Impacts on Distribution Grid

- Additional energy demand of EV charging depends on the behaviors of EV owners, and is less pronounced for comfort-driven behavior.

- Locally, the load in the distribution grid can increase by almost 80%.

![Graph showing the increase in load for different charging scenarios: Workplace Charging, Home Charging, and Publicly Available Chargers. The x-axis represents the type of charging (Price-driven, Comfort-driven), and the y-axis shows the increase in load. The graph indicates a significant increase in load for both types of charging, with a higher increase for Comfort-driven charging.]
Feasible Sites for Public-Private Partnership Identified

- Number of required public chargers at private car parking lots suited for public-private partnerships have been identified

- At 20% EV penetration, 7 public chargers are required at Hotel Einstein; 5 at Burggraben School parking lot
Outlook – Application of Smart Meter Data

- Digital model of St. Gallen’s infrastructure is being augmented with analysis of sgsw’s smart meter data
- Thus, accurate power flow simulations can be conducted to assess challenges and opportunities for energy management in distribution grid
Conclusions

• Customer preferences and behaviors affect revenues, costs and operation of DSO’s EV infrastructure

• As of today, penetration of EVs does not guarantee profitability of existing public chargers; public infrastructure break-even is, at best, 10 years

• Competition from privately-owned EV public chargers decreases, by up to 35%, revenues at DSO’s public chargers

• With developed EV model, DSO is supported in taking decision whether to invest in EV chargers or not