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

Switzerland

- Population: 8,534,667

St. Gallen

- Inhabitants: 75,500
- Commuters: 39,000

**Daily Schedule**

<table>
<thead>
<tr>
<th>Time</th>
<th>Actions</th>
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</thead>
</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

![Monthly Charging Cycles Comparison](chart.png)

- 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

![Graph showing yearly revenues from parking fees and power sales](image)
For Today’s EV Penetration Public Chargers Do Not Reach Break-Even

- Both simulations results and sgsw 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
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

<table>
<thead>
<tr>
<th>EV Penetration [%]</th>
<th>Number of Required Public Chargers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>146</td>
</tr>
<tr>
<td>5</td>
<td>402</td>
</tr>
<tr>
<td>10</td>
<td>552</td>
</tr>
<tr>
<td>20</td>
<td>824</td>
</tr>
</tbody>
</table>
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 behaviors of EV owners, and is less pronounced for comfort-driven behavior.

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

![Graph showing impact of price-driven and comfort-driven charging behaviors on distribution grid load.](image-url)

EV Penetration 20%
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

Distribution of Chargers
- Increasing Required Number of Chargers

Hotel

School

Distribution of Chargers

Demand [kW]
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.