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

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Outline

- Introduction
- Methodology
- Results and Discussion
- Conclusions

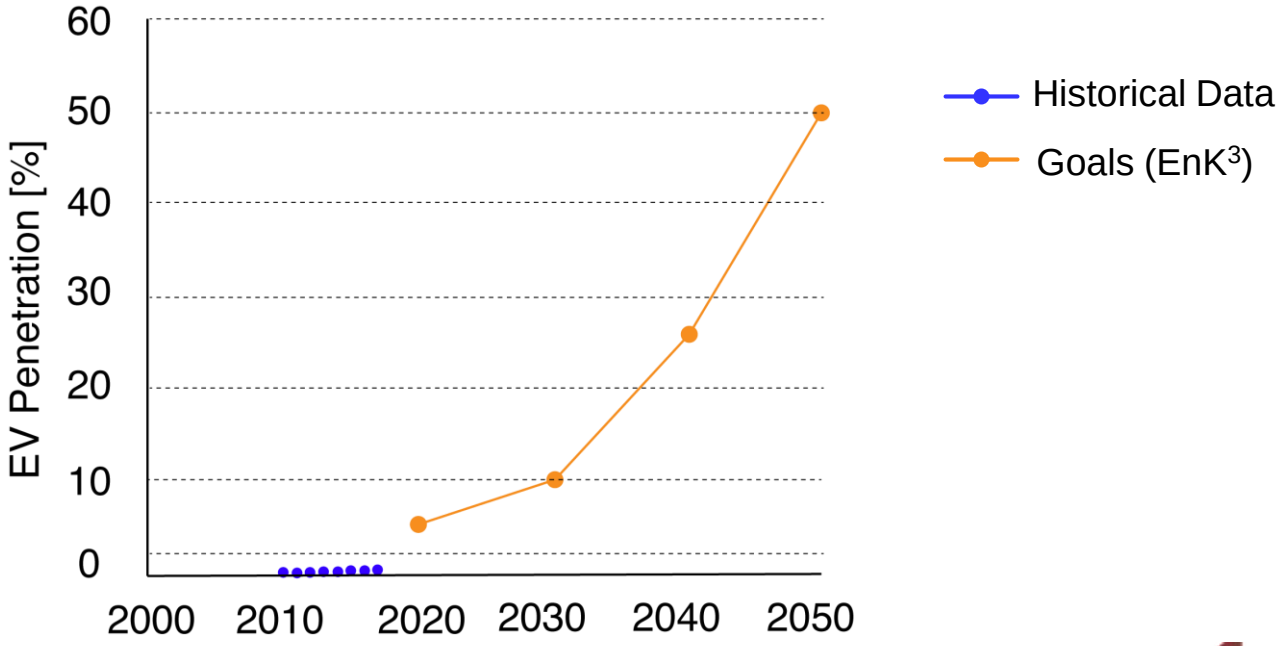
Introduction

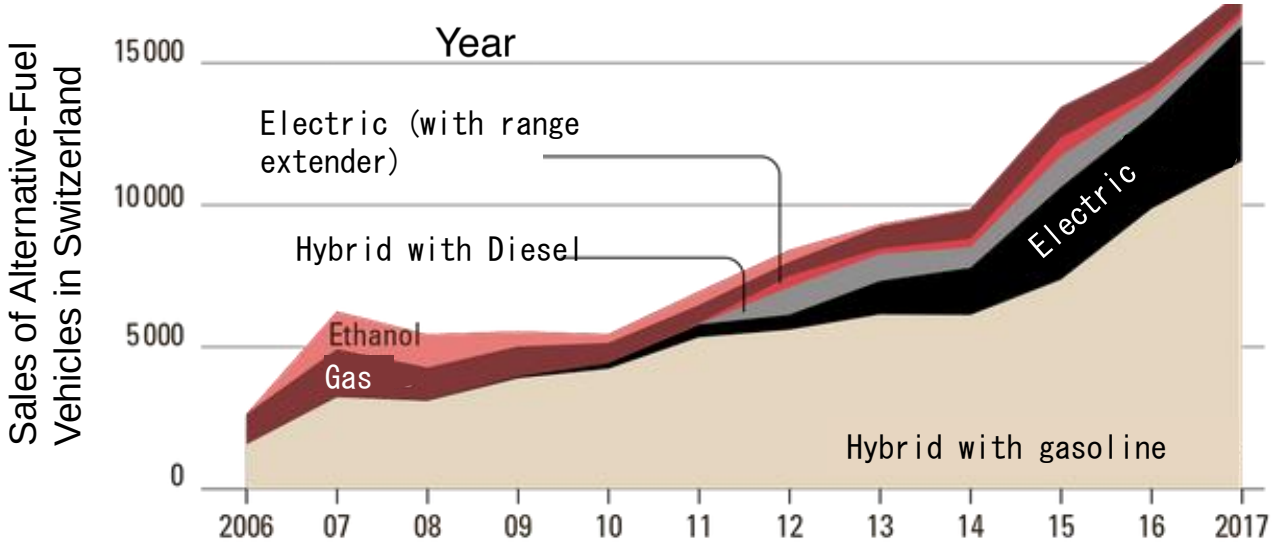
- While today's penetration of EVs is 0.3% in City of St. Gallen, City's Energy Concept (EnK³) plans 50% penetration by 2050

- 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

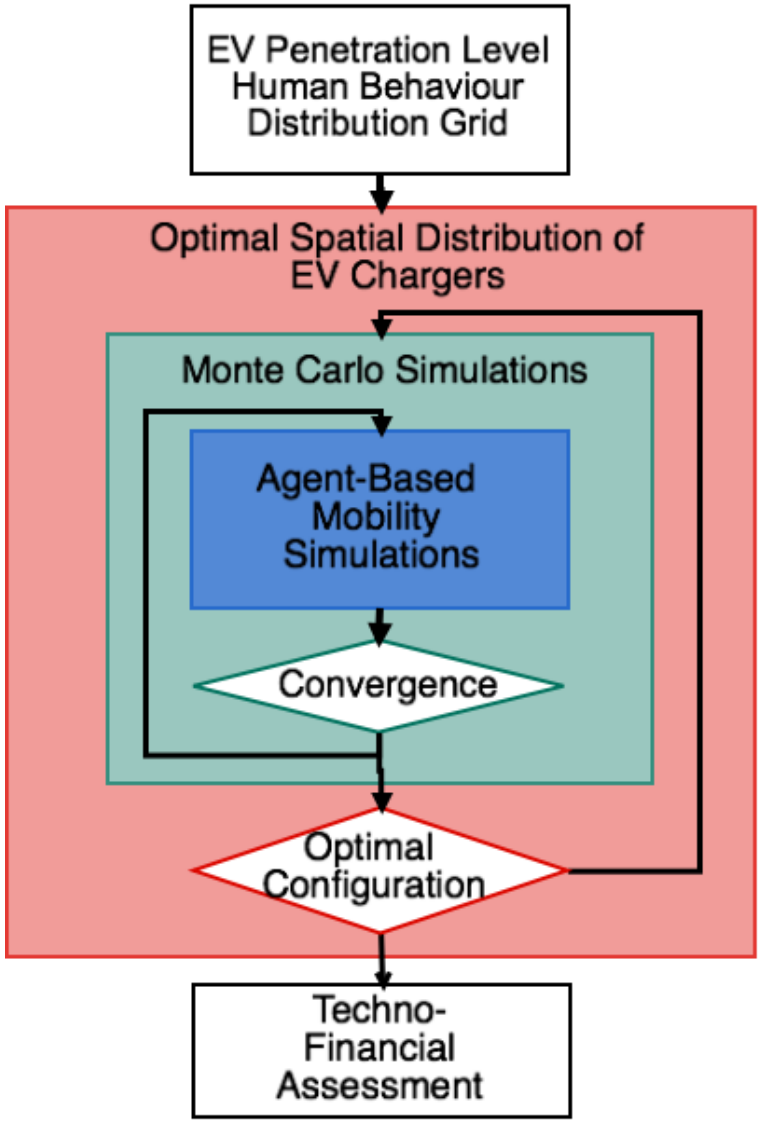
- Digital model integrates
  - geo-referenced data of population
  - buildings
  - energy infrastructure and
  - mobility infrastructure

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



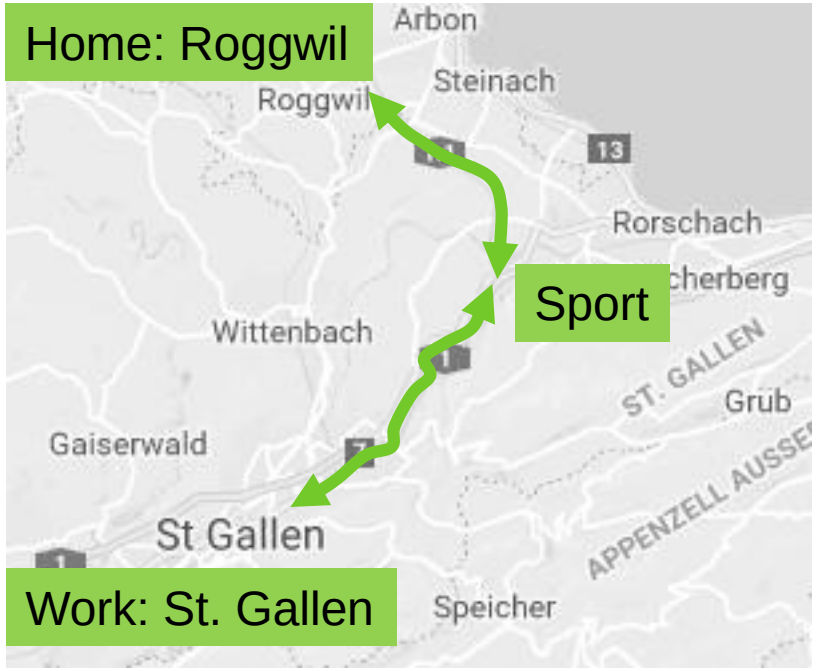
Agent-Based Models Account for Individual Characteristics

- 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)

Switzerland	
population	8‘534‘667
St. Gallen	
inhabitants	75’500
commuters	39’000

Max Mustermann

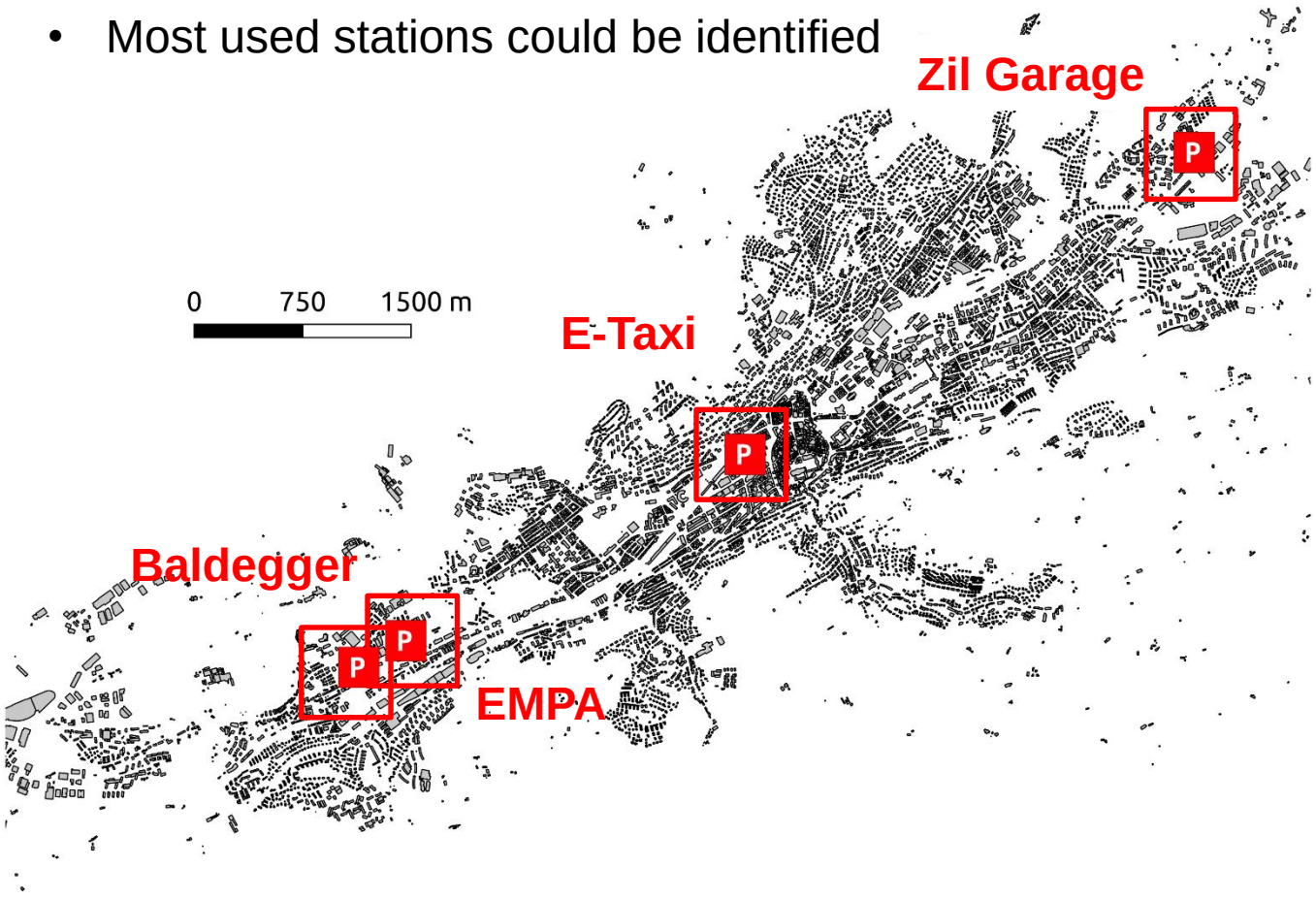
Age: 31
Sex: Male
Home Municipality: Roggwil
Job Municipality: St. Gallen
Job Status: Full-time employed
Job Sector: Tertiary

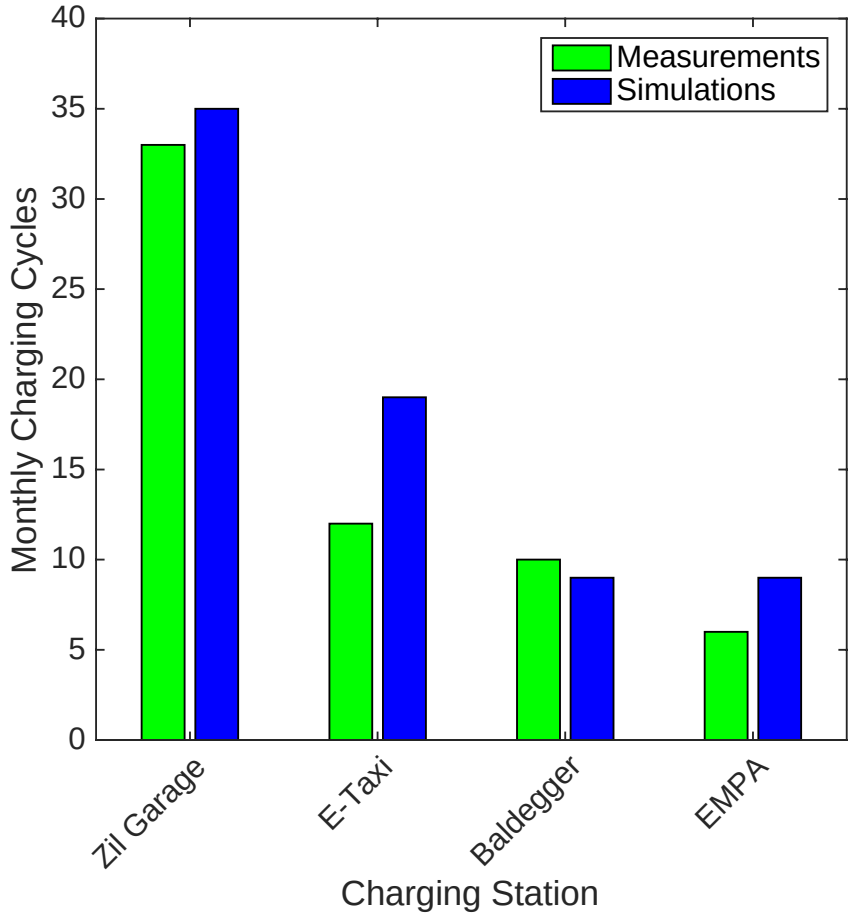


Daily Schedule	
Time	**Actions**
08:13 – 09:00	• Leave home • Travel to work
08:00 – 18:29	• Work
18.30 –19.05	• Travel to sport activities
18:30 – 22:00	• Sport activities
22:00 – 22:45	• Travel home
22:45 …	• Home

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

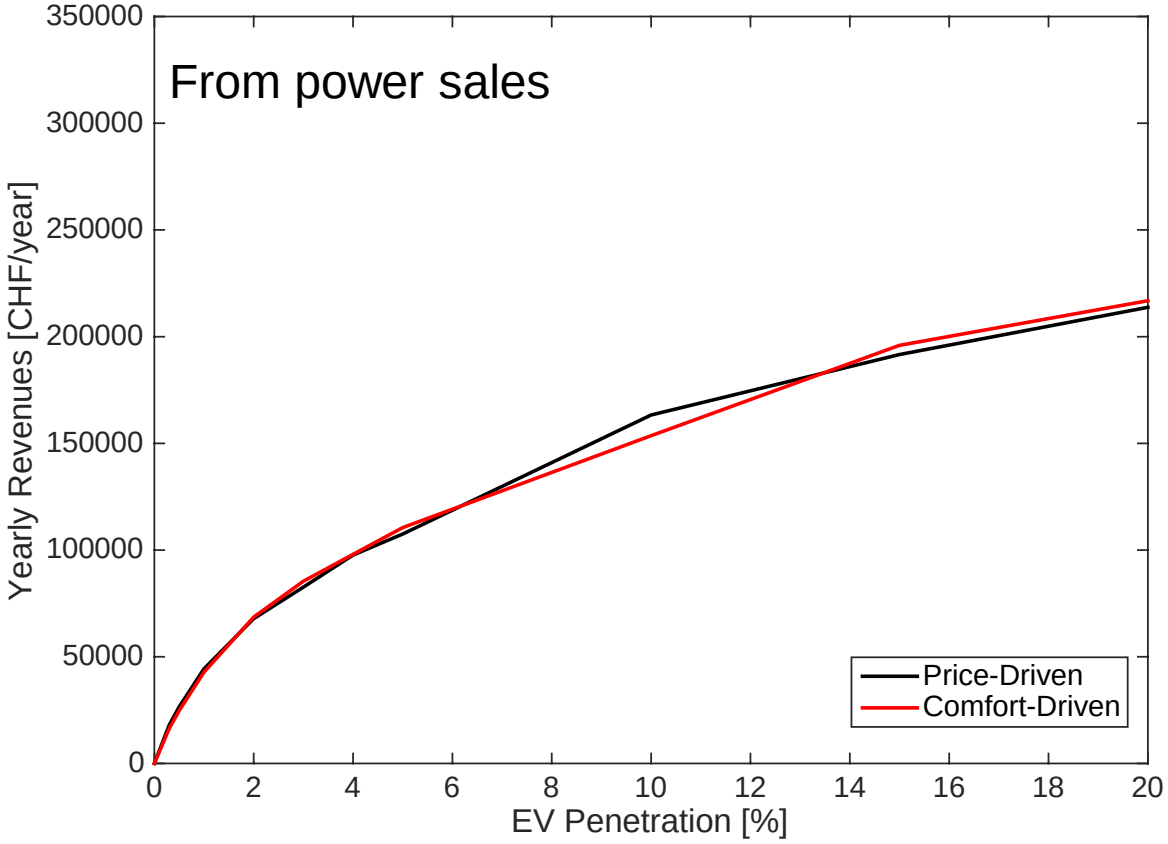


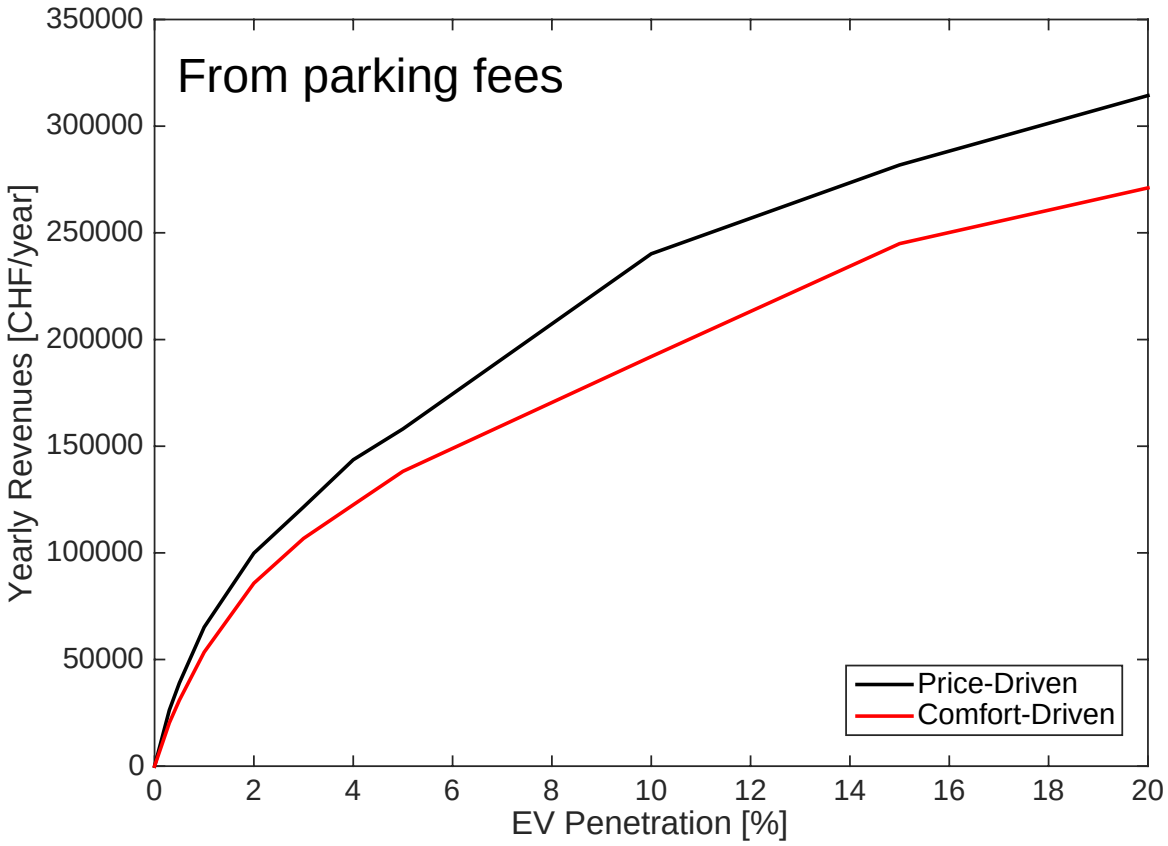


Results

Revenues from Parking Fees Are Best Business Model To Operate EV Infrastructure

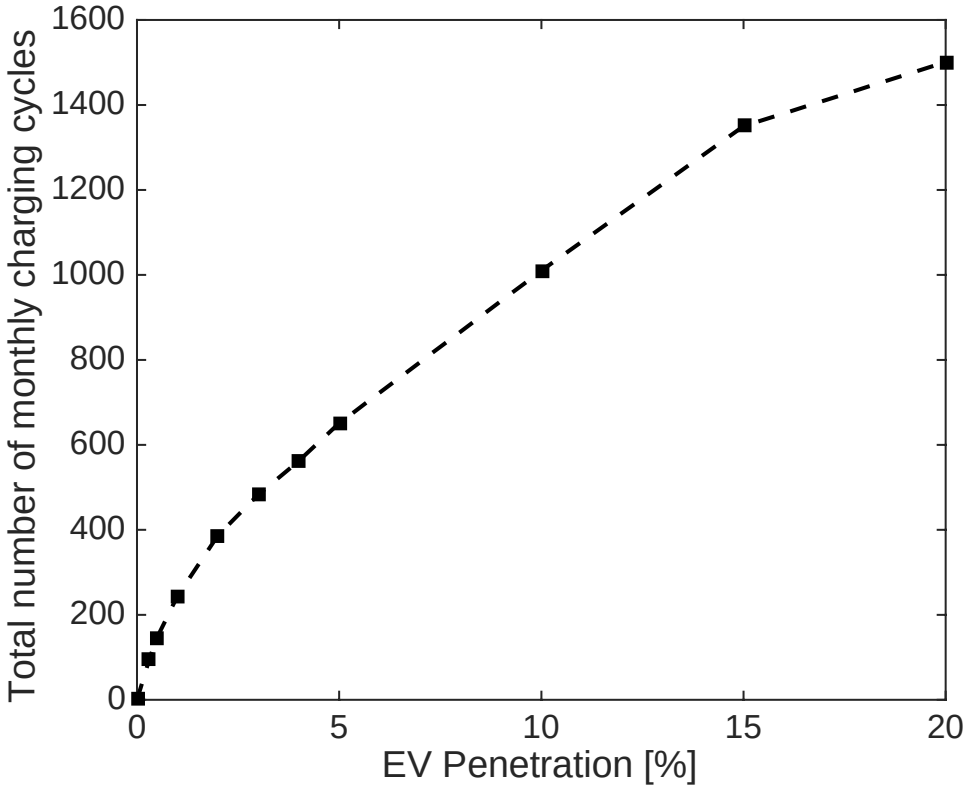
- Parking fees, based on prevailing market conditions, yield larger revenues for city's utility than tariff based on power used to charge EV
- Revenues from parking fees are particularly impacted by behavior of customers

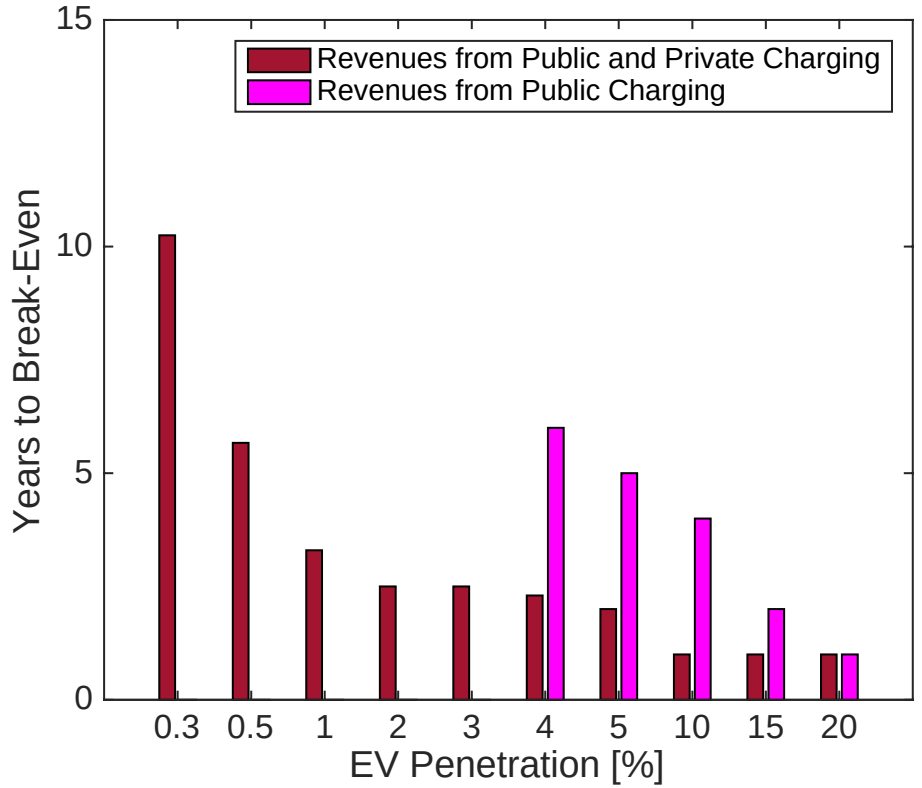




For Today's EV Penetration Public Chargers Do Not Reach Break-Even

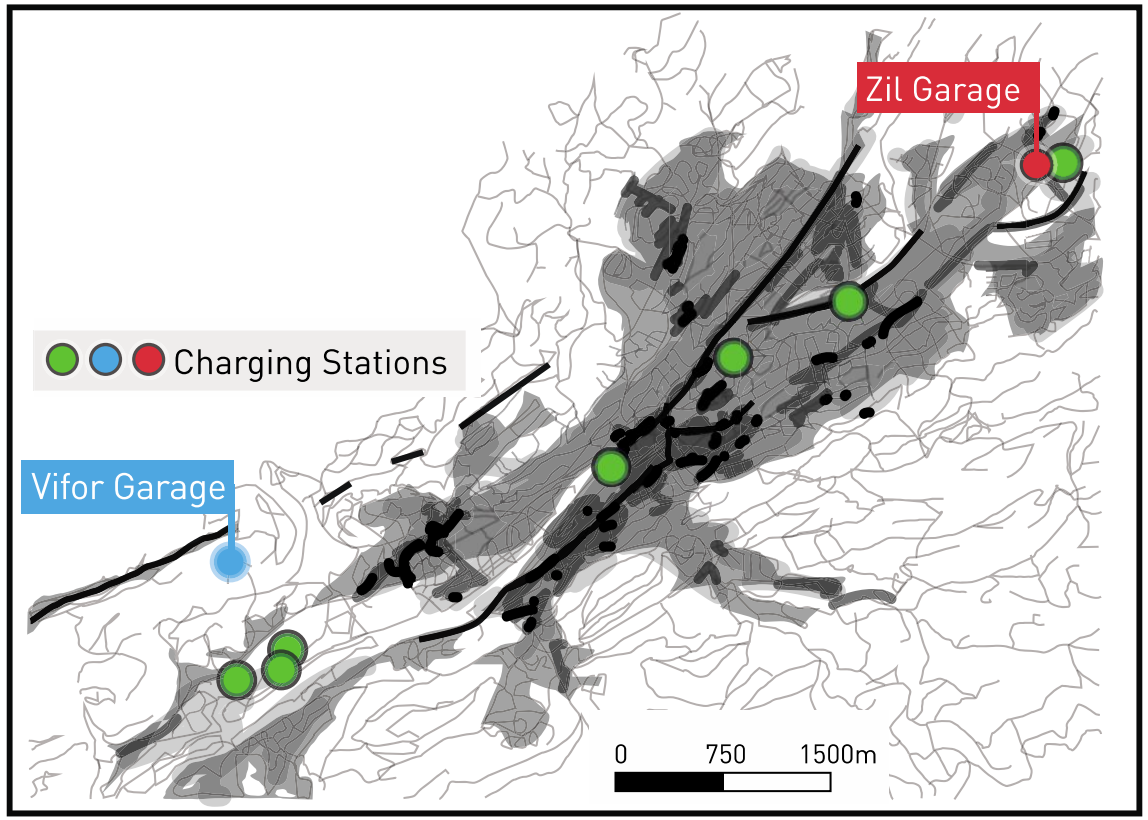
- Both simulations results and sgsw measurements show underusage of publicly available chargers
- For City's existing public EV chargers, load factor rapidly increases with increasing EV penetration
- For public chargers, break-even can be reached only with EV penetration exceeding 4%
- Considering also 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%

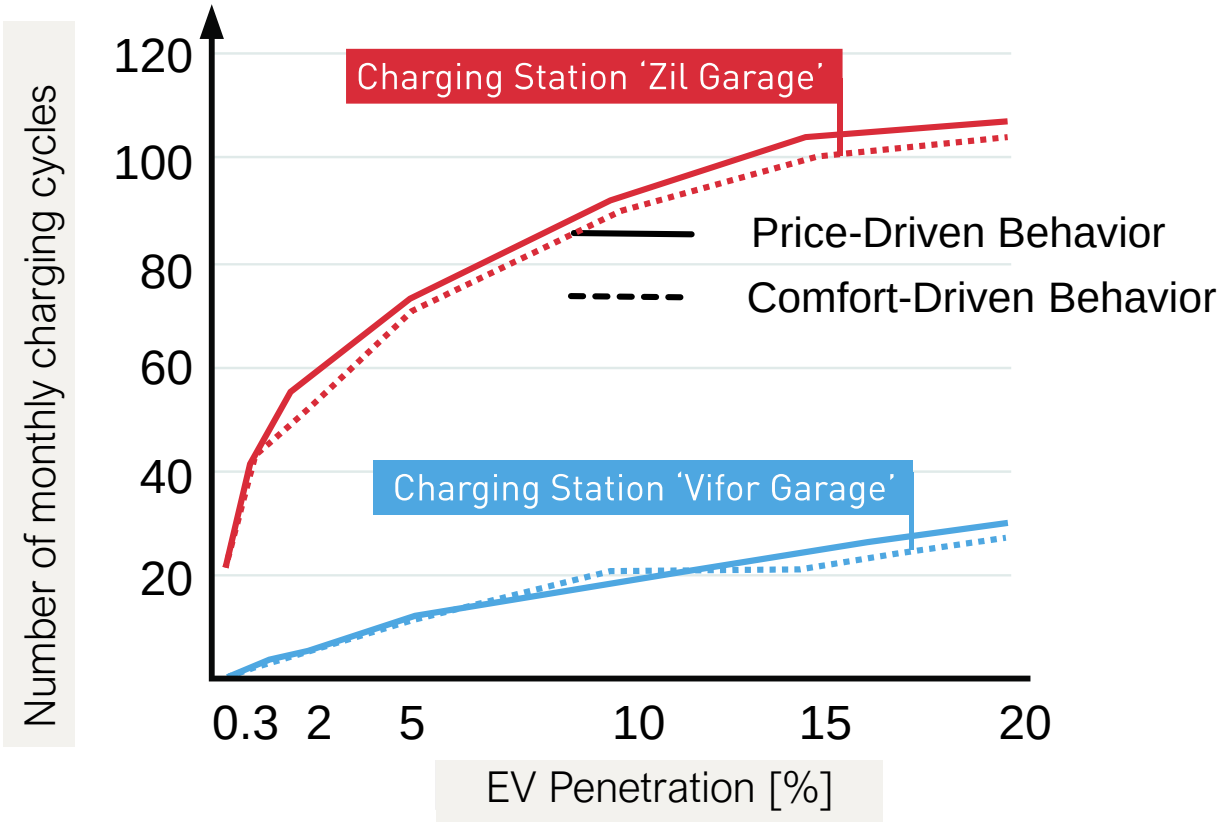




Usage of Specific EV Charging Stations Quantified

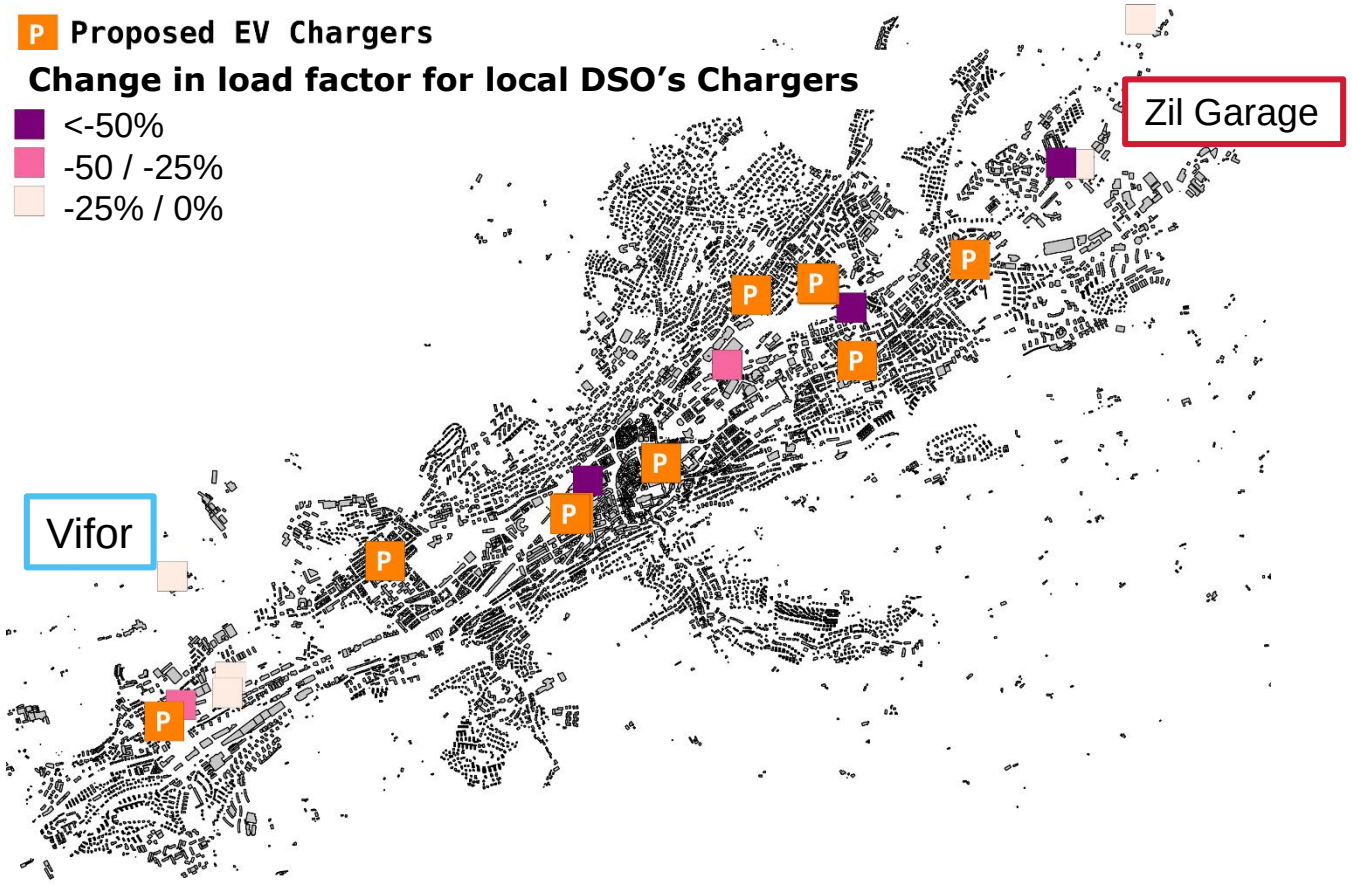
- Simulations quantify, over range of EV penetrations, usage of specific public EV chargers, as well as impacts of human behaviour and preferences
- More than 80% of charging stations will not recover their investment and maintenance costs

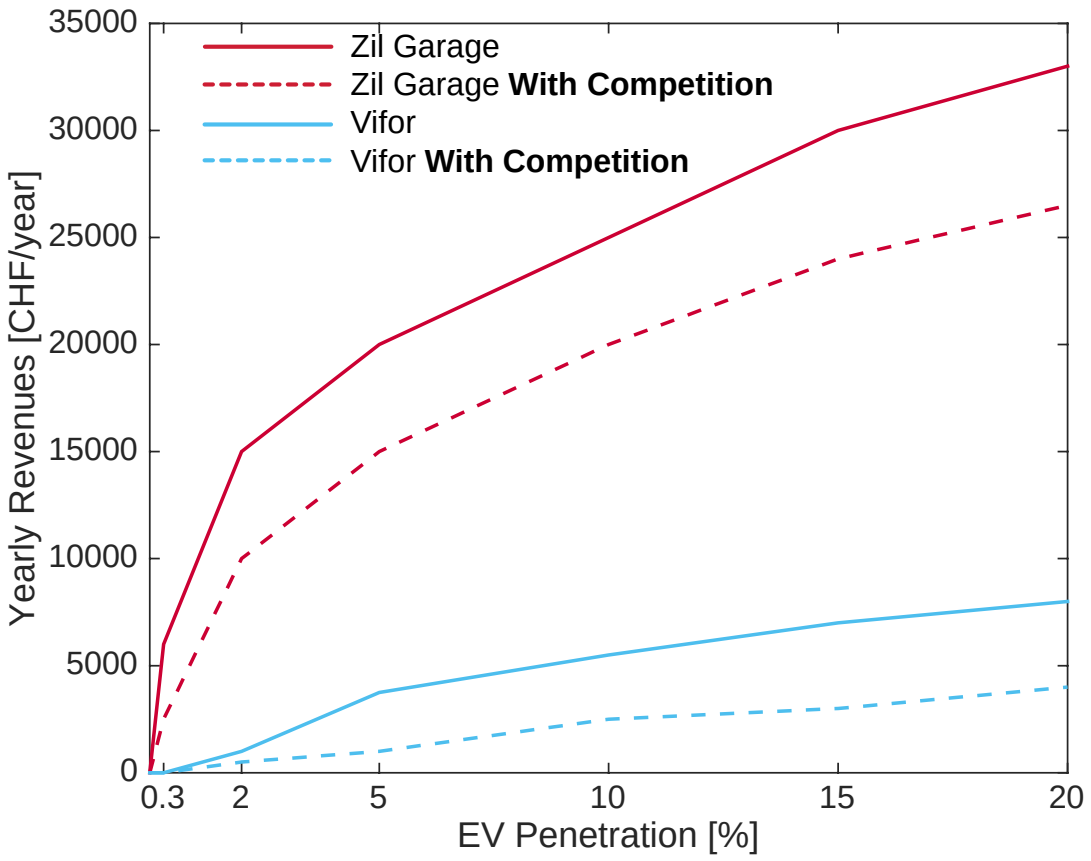




Privately-Owned Public Chargers Adversely Impact Local DSO

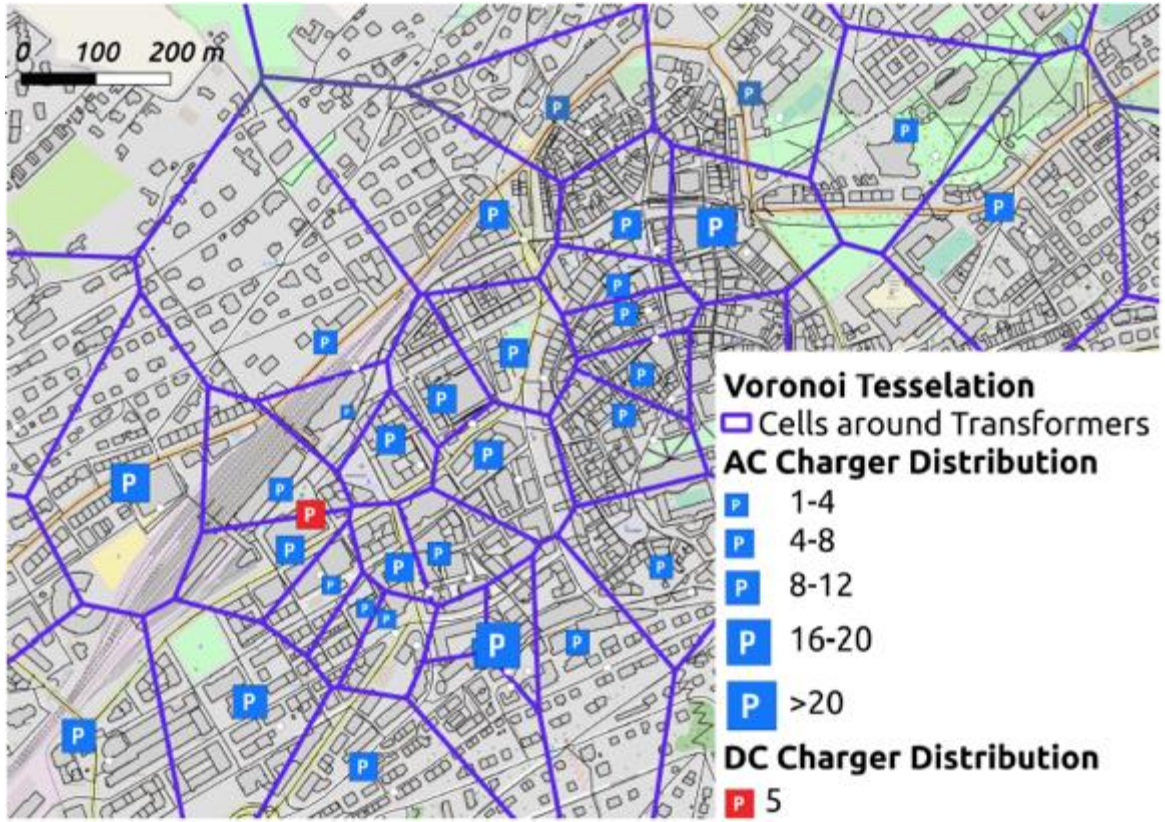
- 10 new, privately-owned EV public chargers, to be installed by 2020, will decrease usage of DSO's existing 23 chargers, with 35% decrease in load factors for 2% EV penetration
- Competition from privately-owned EV public chargers decreases revenues by up to 35% at individual





Placements of Public Chargers That Optimize Usage Determined

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

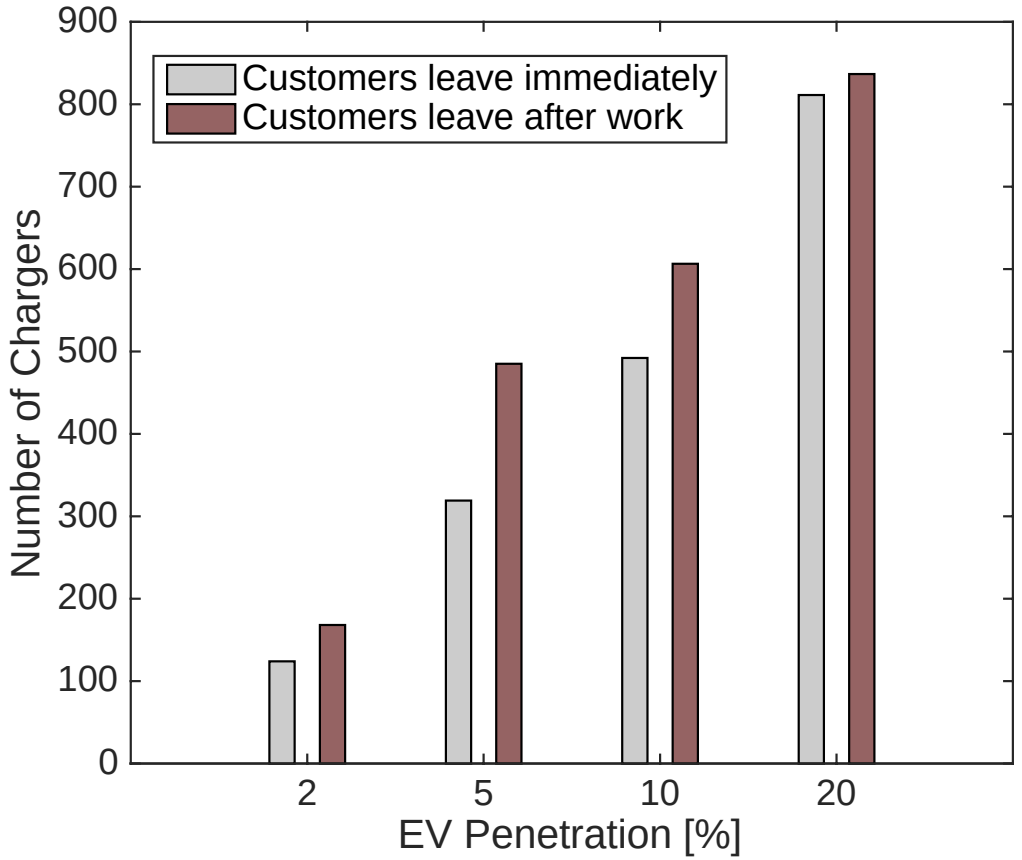


EV Penetration 20%

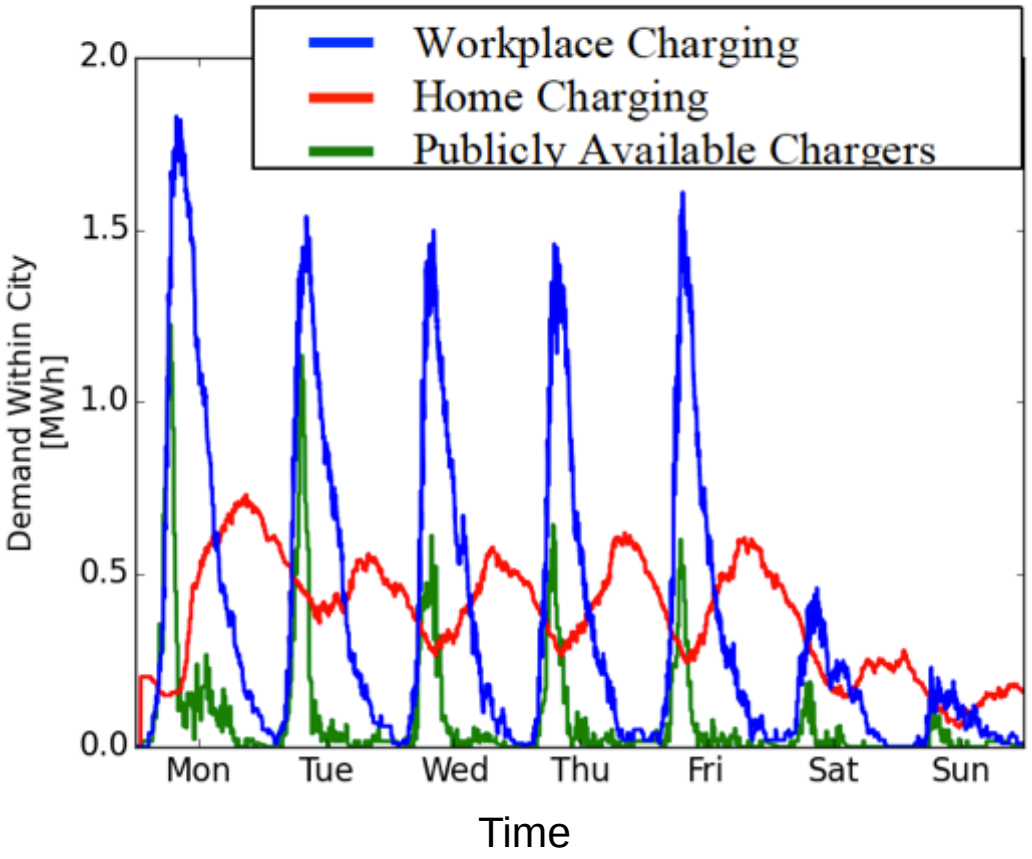
Required Number of Public Chargers Increases with EV Penetration

- 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

EV Penetration [%]	Number of Required Public Chargers
2	146
5	402
10	552
20	824



Additional Energy Demand for EV Charging Quantified



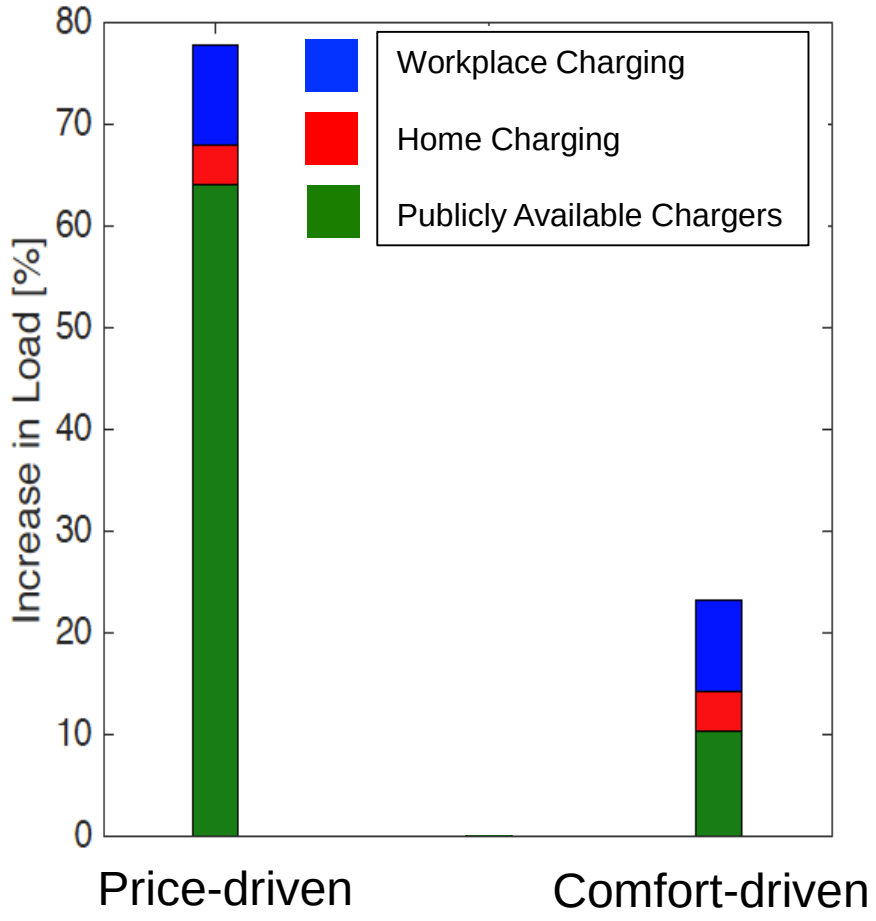
- Additional energy demand of EV charging comes mainly from workplace and public charging
- Sharp peaks of public charging may require use of energy management solutions as EV penetrations increase

EV Penetration 20%

Different Behaviors of EV Owners Have Different Impacts on Distribution Grid

- Additional energy demand of EV charging depends of behaviours of EV owners, and is less pronounced for comfort-driven behaviour

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



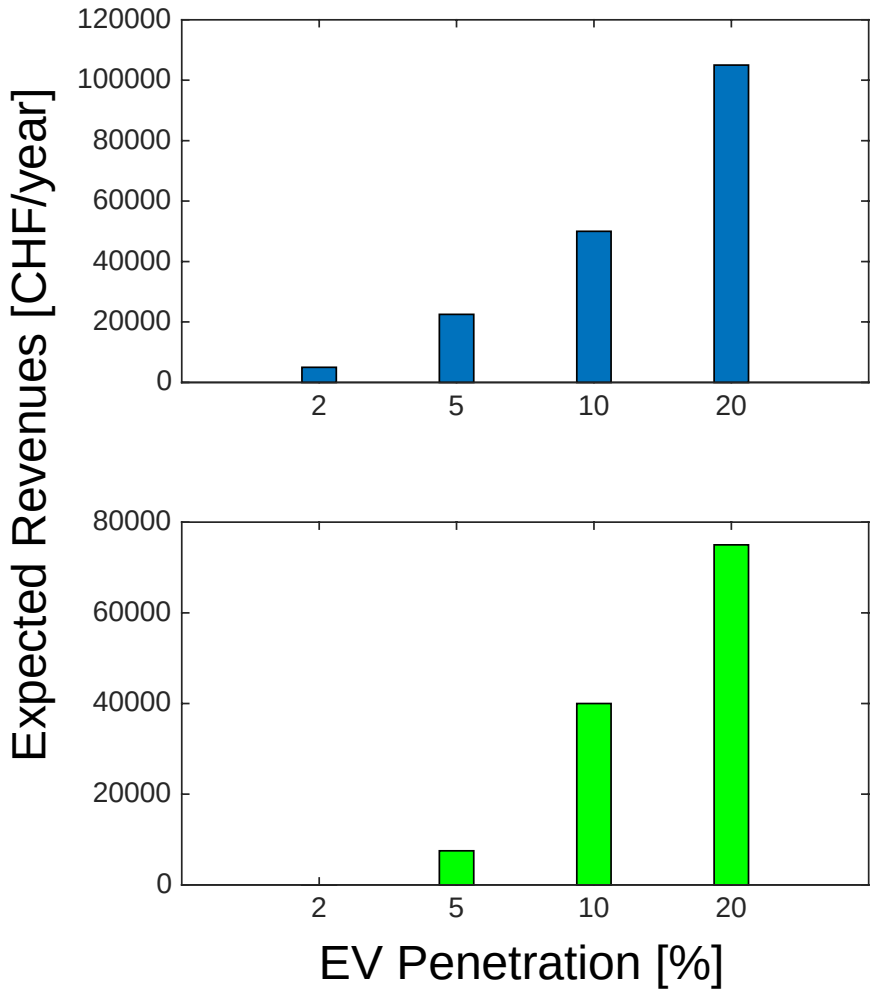
EV Penetration 20%

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

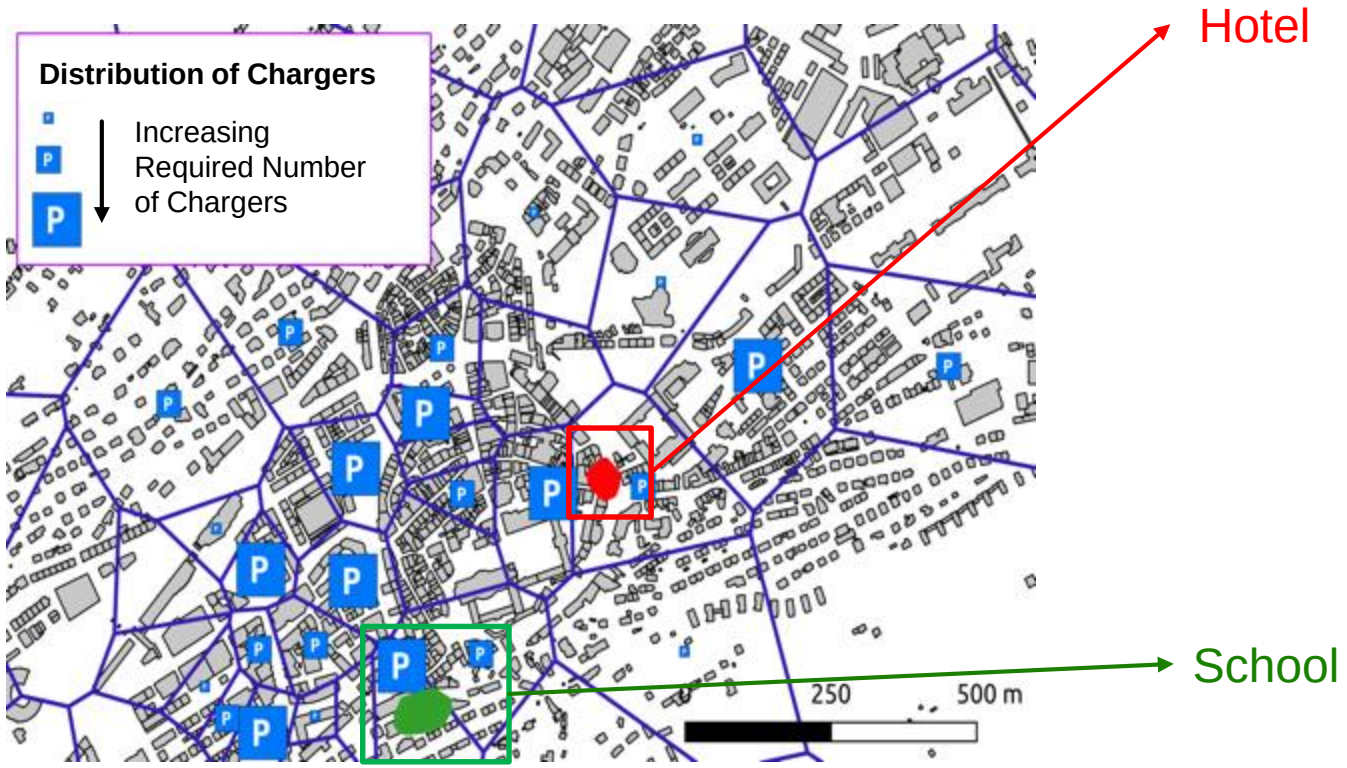
Hotel Einstein

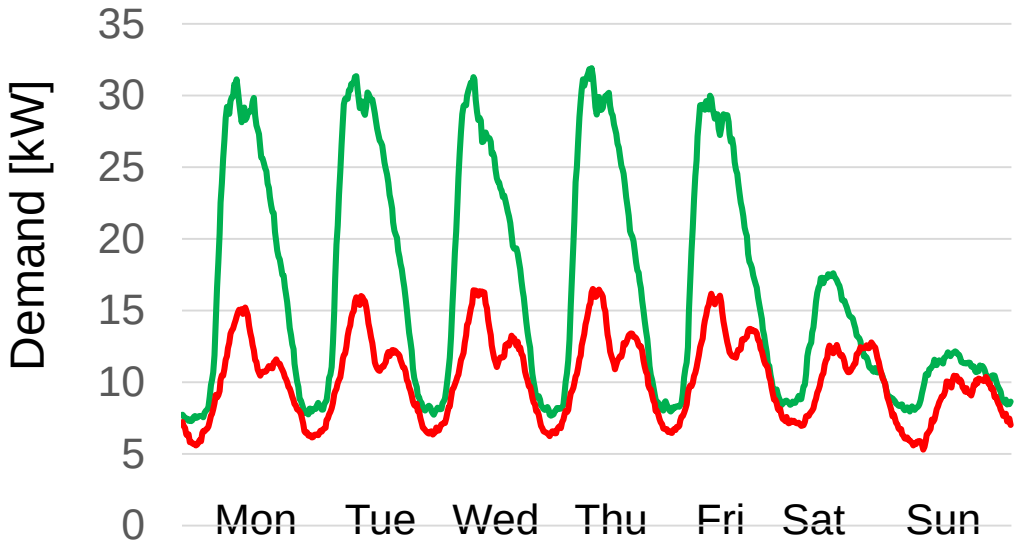
Burggraben
Cantonal School



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