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First steps towards incorporating E-charging infrastructures for heterogeneous consumer segments in an energy systems optimization model

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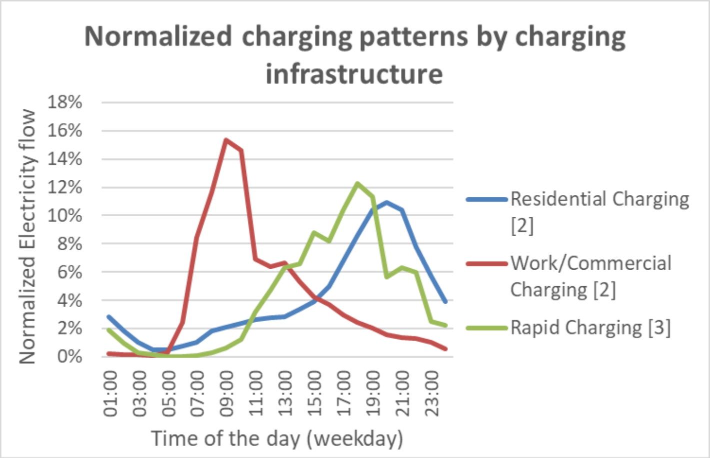
Motivation – Electric Vehicle (EV) adoption

- **Electric cars** are often referred to as an indispensable vehicle technology to transform the transportation sector towards reaching **ambitious climate targets**

- Rapid increase of EVs requires large amounts of electricity, imposing challenges for the electricity grid [1]

- Consumers show **differing demand profiles and timings** depending on the charger power and charging locations [2, 3]

- **Consumer charging behavior** plays a critical role for a successful uptake of EVs



[1] International Energy Agency (IEA), "Net Zero by 2050 - A Roadmap for the Global Energy Sector," 2021.
[2] T. Dodson and S. Slater, "Electric Vehicle Charging Behaviour Study," 2019.
[3] Celli, G., Soma, G. G., Pilo, F., Lacu, F., Mocci, S., & Natale, N. (2014). Aggregated electric vehicles load profiles with fast charging stations. Proceedings - 2014 Power Systems Computation Conference, PSCC 2014.

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Research Gap & Aim

- Energy System Models (ESMs) are **cost-optimizing tools** with a techno-economic foundation: they can simulate EV charging infrastructures, but they are **limited in representing behavioral consumer preferences** [4, 5]

- However, **consumer preferences are crucial regarding EV charging**, as they can determine how consumers use different charging infrastructure types

Aim

Enhance an energy system model by representing an **interplay between heterogenous consumers and their usage of EV charging infrastructure**

[4] Schäfer, "Introducing Behavioral Change in Transportation into Energy/Economy/ Environment Models," 2012.
[5] G. Venturini, J. Tattini, E. Mulholland, and B. Gallachóir, "Improvements in the representation of behavior in integrated energy and transport models," Int. J. Sustain. Transp., vol. 13, no. 4, pp. 294–313, 2018

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Agenda

1. Motivation

2. Methods
   a. Model framework
   b. Case study description

3. Preliminary results & Discussion

4. Conclusions & Future Work

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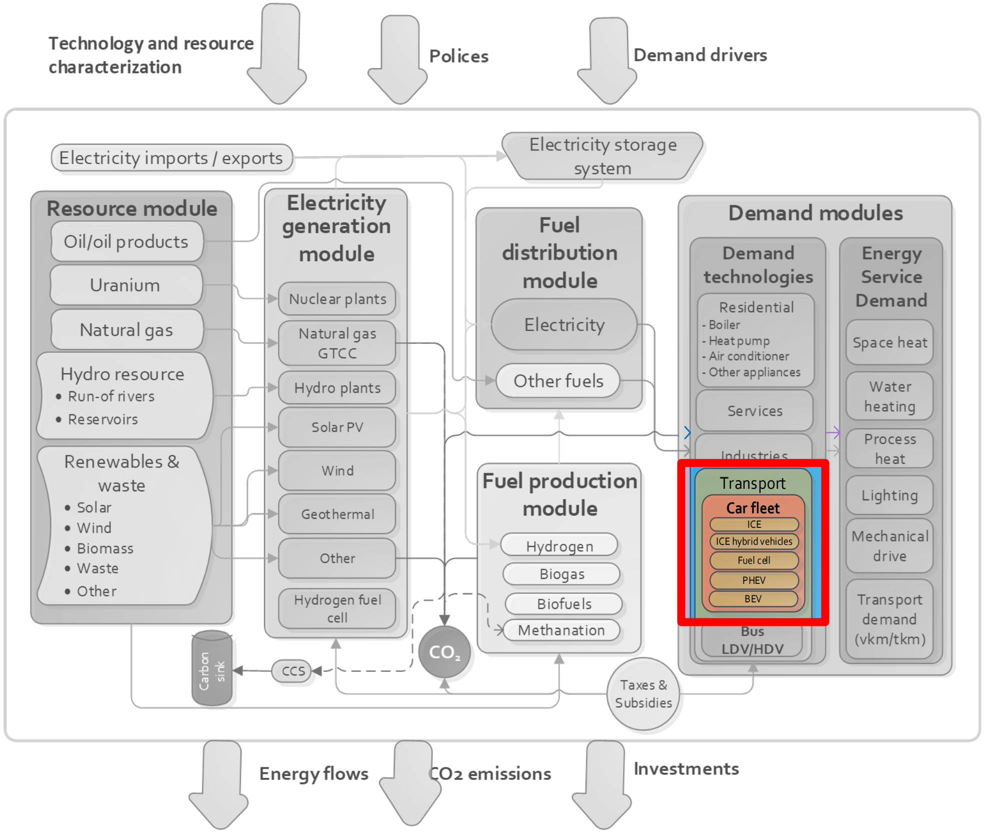
Swiss TIMES Energy Systems Model

STEM: Swiss TIMES Energy Systems Model [6, 7]

- Entire Swiss energy system
- **Cost-optimizing**
- Bottom-up **techno-economic** technology-characterization (technology-rich)
- **Long time horizon** (2050+) with hourly resolution
- Scenarios for **technologies**, **energy consumption**, and **CO_2**



[6] R. Kannan and S. Hirschberg, "Interplay between electricity and transport sectors – Integrating the Swiss car fleet and electricity system," *Transp. Res. Part A Policy Pract.*, vol. 94, pp. 514–531, 2016

[7] R. Kannan, E. Panos, T. Kober, and S. Luh, "A supplementary documentation to the Swiss TIMES Energy System Model (STEM) - Updates on transportation module and development of STEM elastic variant," 2019.

Applied Model framework

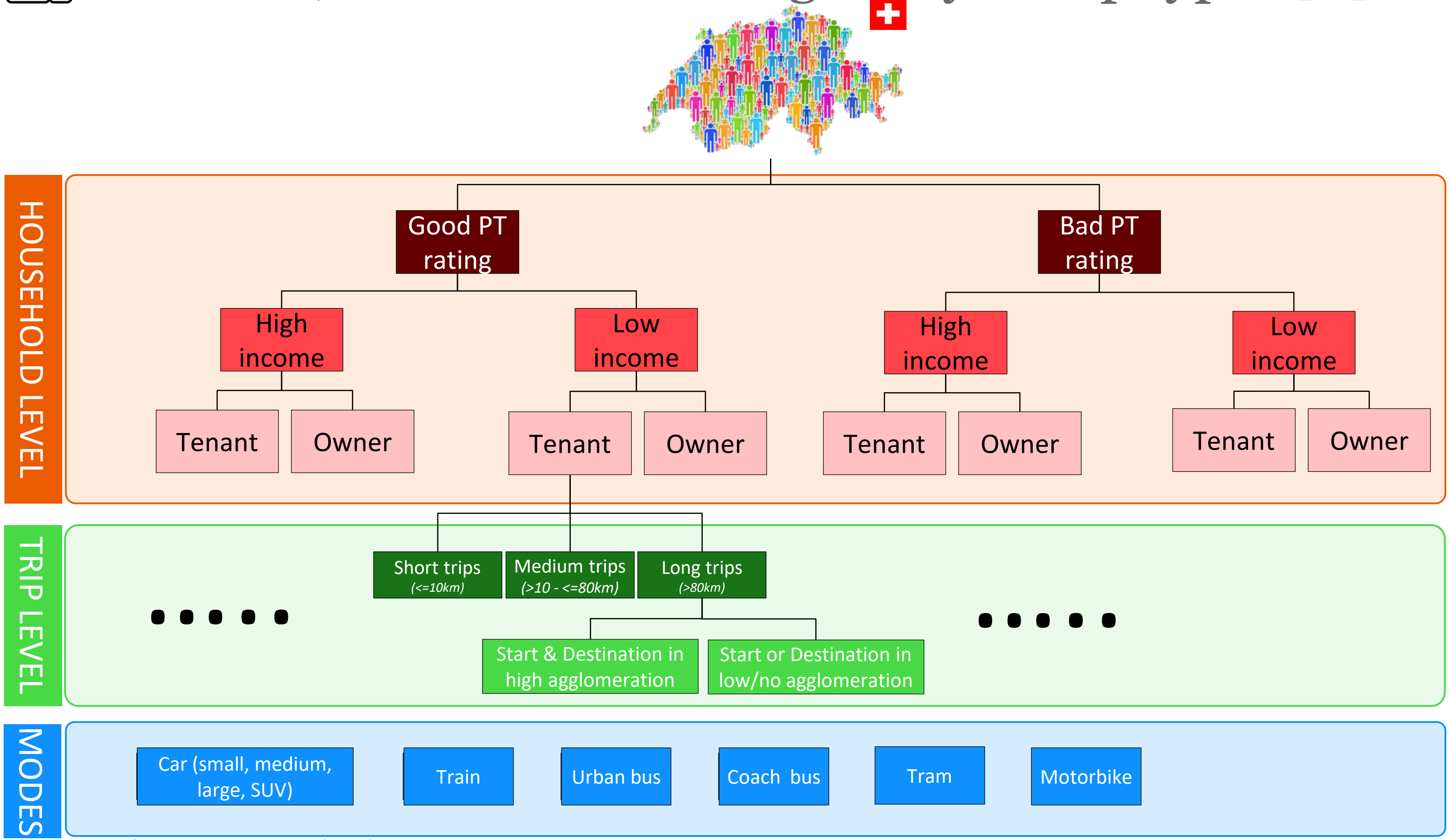
- **Standalone passenger transport module** of STEM *
- **Testbed model for novel methodological features** in STEM
- Calibrated for nationwide fuel consumption and mobility demand
- Focus on cars
- Cost-minimizing objective function: $min\left(\sum_{t\, \in years}(1+d_t)^{t-2010} * Annual\ Cost(t)\right)$

New methodological features:

1. **Consumer heterogeneity** through eight consumer segments
2. Distinguishing **trip types** by distances
3. Enhanced **electric charging infrastructure** for cars

**Since the holistic perspective of STEM, which reflects cross-sectoral impacts, is not available in the sectoral model used in this work, the model results should not be compared. Thus, the results of this work should be seen as illustrative to understand methodological enhancements.*

1 & 2) Consumer heterogeneity & trip types [8]



[8] Bundesamt für Statistik / Bundesamt für Raumentwicklung. (2017). *Verkehrsverhalten der Bevölkerung. Ergebnisse des Mikrozensus Mobilität und Verkehr 2015.*

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3) Enhanced electric charging infrastructure for cars

- Two types of charging infrastructure: **Home Charging (HC) and Public Charging (PC)**
  - Investment & usage costs [10]
  - Annual utilization rate [9]
  - Hourly charging patterns [2, 3]
  - Accessibility can be controlled by consumer segment

- **Range anxiety**: When BEVs drive long-distance trips, they must use a public charging station once distance is driven that relates to 80% of the battery capacity.

[2] T. Dodson and S. Slater, "Electric Vehicle Charging Behaviour Study," 2019.
[3] Celli, G., et al. (2014). Aggregated electric vehicles load profiles with fast charging stations. Proceedings - 2014 Power Systems Computation Conference 2014.
[9] PwC. (2021). Electric vehicles and the charging infrastructure: a new mindset? (pp. 1–7).
[10] International Council on Clean Transportation (M. Nicholas). (2019). Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas (Issue 14)

Case study: access to home charging for tenants

Rationale:

- Most charging events in the future are expected to take place at home [11]
- But currently, tenants have yet limited rights to install charging infrastructure at their homes [12]

Scenarios:

- Baseline: Tenants will receive **no access to home charging**
- S1/2/3/4: Tenants can **access home charging** infrastructure **from 2020/2030/2040/2050**

Research Questions:

→ Do tenants **switch** from public charging to home charging once available?

→ Does it come to **lock-in effects** when home charging becomes later available for tenants?

→ What are the **systemic cost benefits** when home charging becomes sooner available to tenants?

Assumptions:

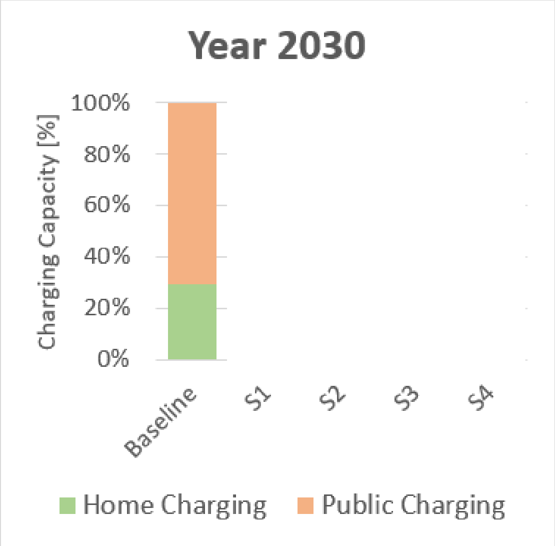
- Technical lifetime of charging infrastructure: 20 years
- Vehicle CO_2 standards & hourly electricity price profile from climate ambitious STEM scenario

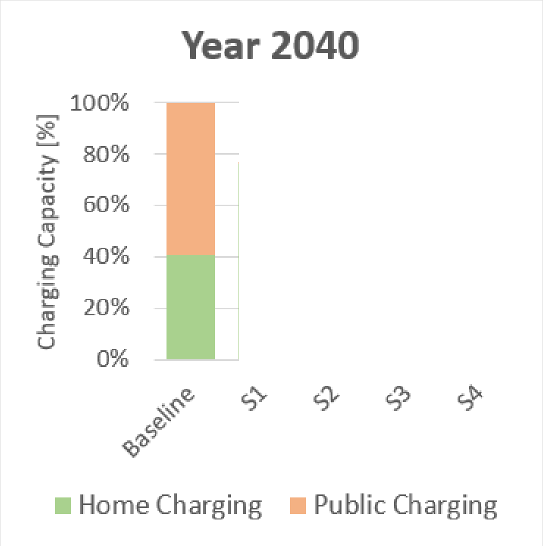
[11] Patt, A. (2021). *A call for charging points at home*. https://ethz.ch/en/news-and-events/eth-news/news/2021/02/a-call-for-charging-points-at-home.html

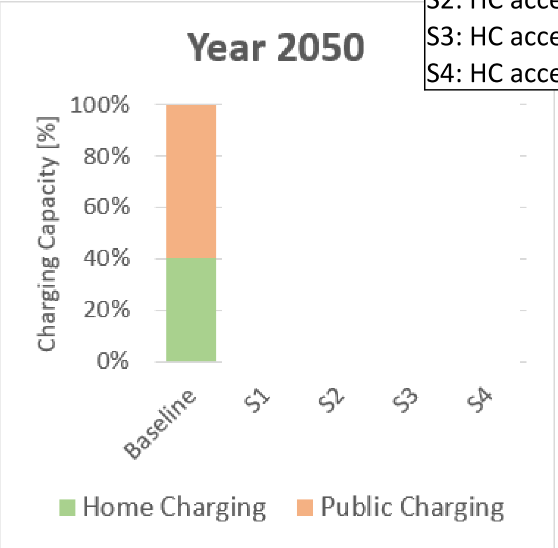
[12] Die Bundesversammlung - Das Schweizer Parlament, “Mieterinnen und Mieter sollen Elektroautos laden können.” 2021, Accessed: Aug. 28, 2021. [Online].

Preliminary Results & Discussion

Scenario overview:
Baseline: no HC access
S1: HC access from 2020
S2: HC access from 2030
S3: HC access from 2040
S4: HC access from 2050







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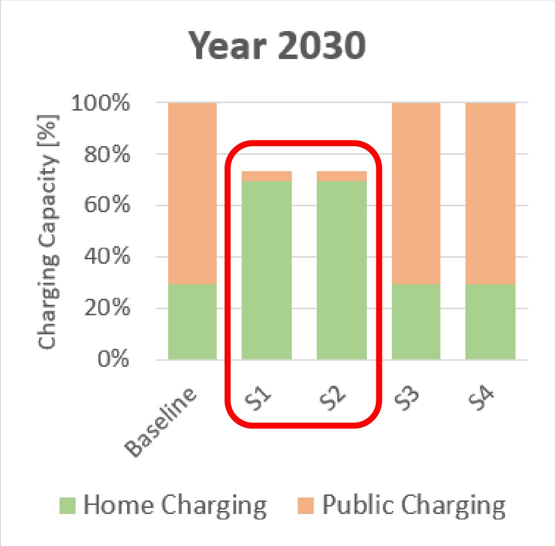

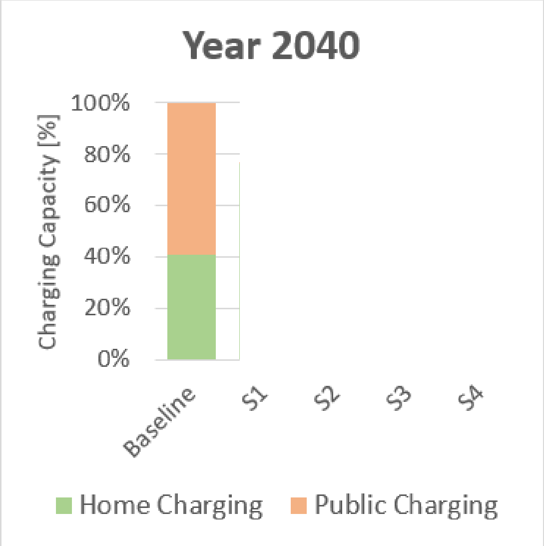

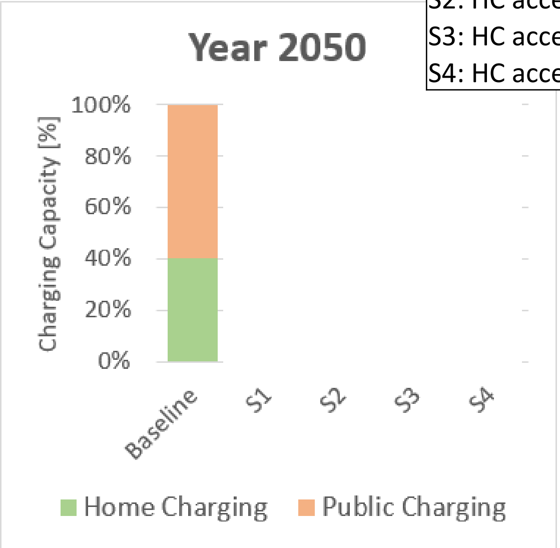

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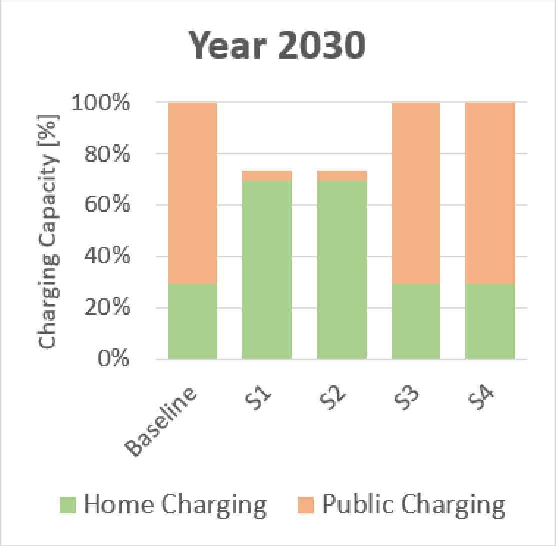

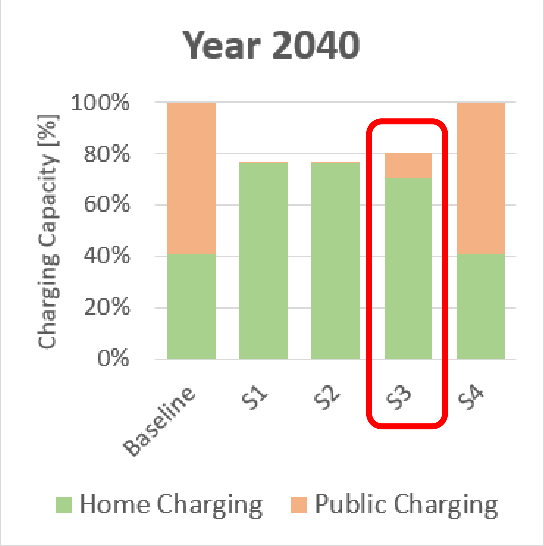

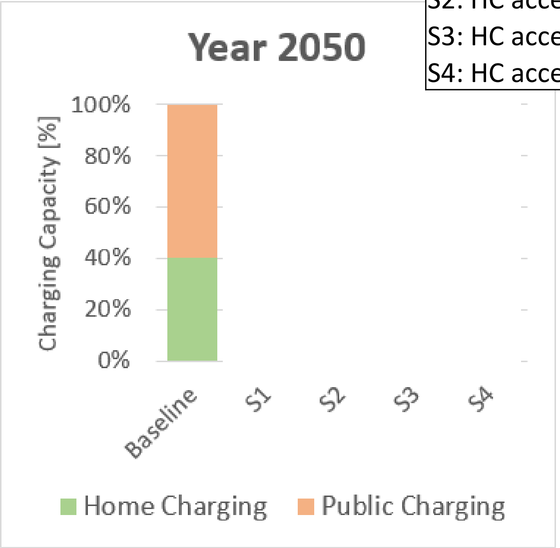

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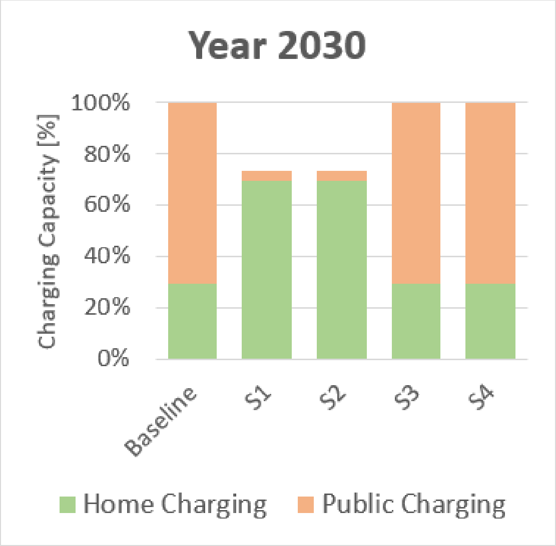

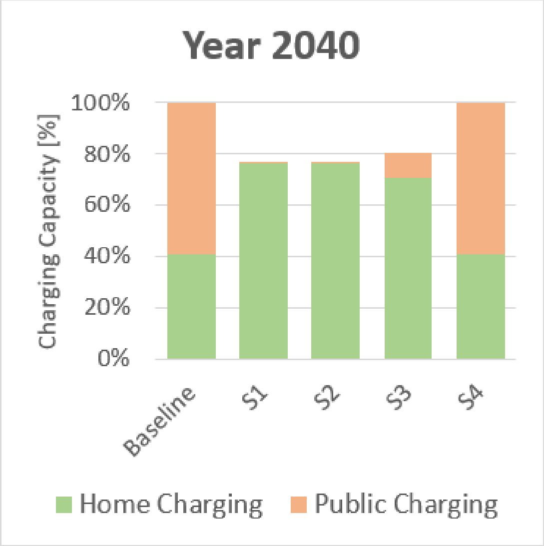

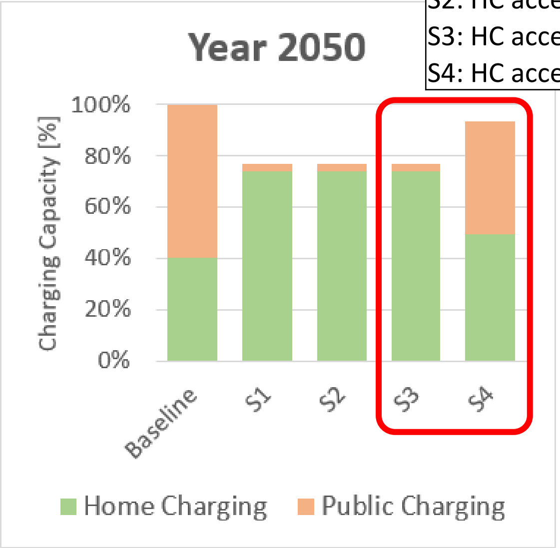

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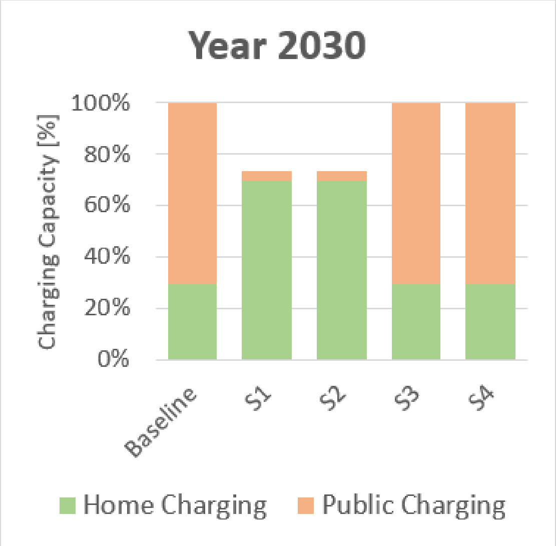

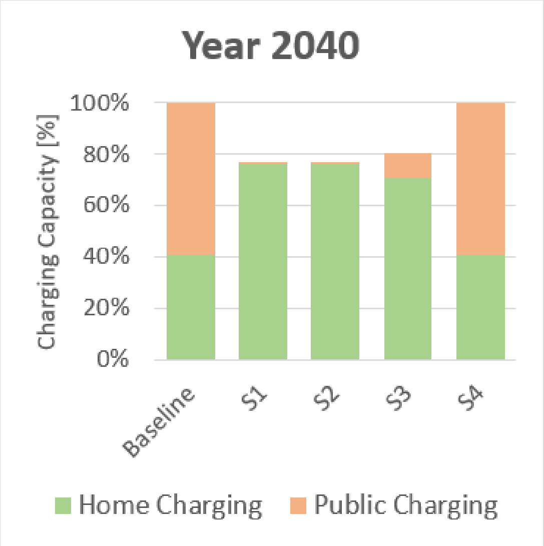

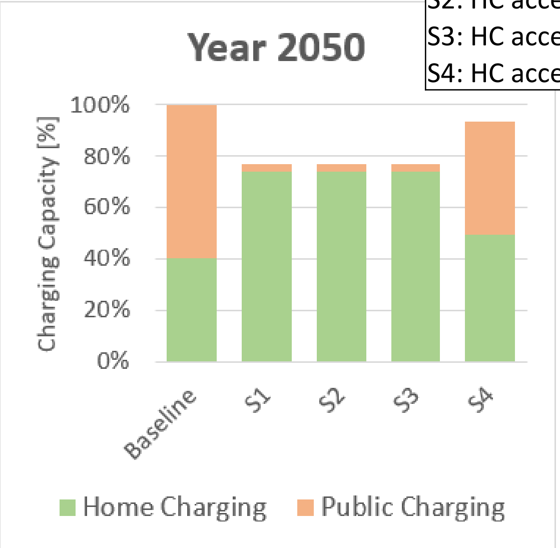

1. Tenants start shifting to home charging once it becomes available: But the later this happens, the more public charging infrastructure is already installed. Thus, it comes to **longer delays** until existing public charging infrastructure is substituted by more home charging infrastructure
2. Once all consumers have access to home charging, only **few public charging capacity remains necessary**
3. When tenants can access home charging, **less total capacity** of charging infrastructure is necessary
4. **Limitation: Behavioral disutility** to not buy a BEV without access to home charging is not represented

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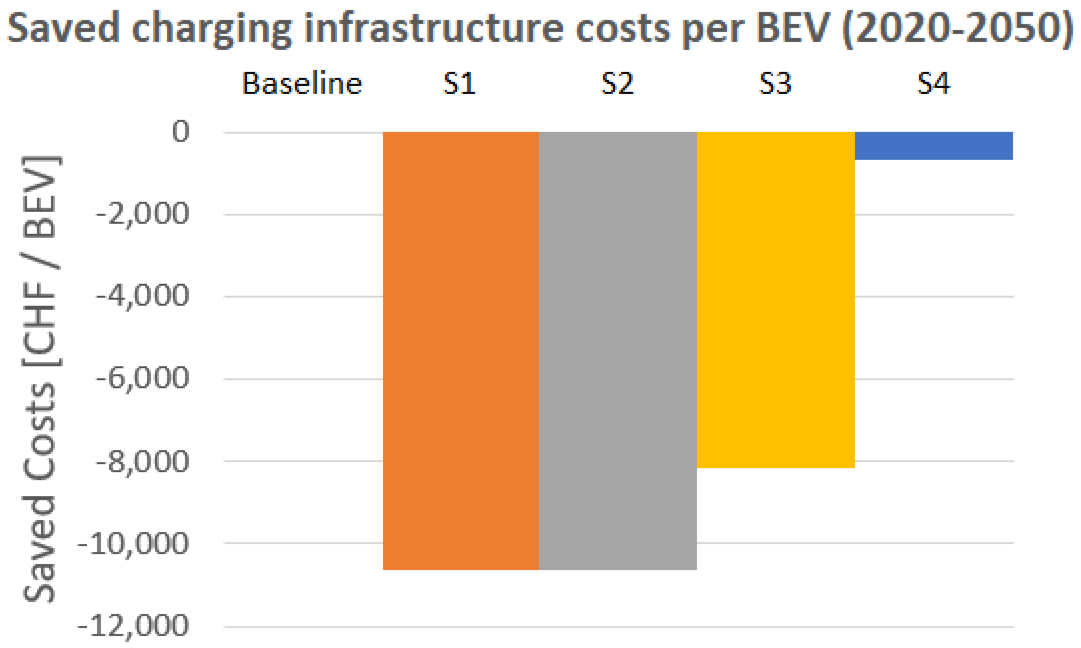

- The earlier consumers can access home charging, **the lower are the systemic costs** for charging infrastructure per BEV

Conclusions & Future Work

Conclusions:

- Earlier home charging access for tenants leads to **reduced total required charging capacity and reduced systemic costs**
- The later home charging becomes available to tenants, the more public charging infrastructure is built up, which leads to **longer transition times**

Future Work:

- Improved control of **charging infrastructure capacity buildup and usage**: At what times do which consumers use which charging infrastructure?
- Explicit representation of **charging duration**
- Implementation of **work/commercial charging** infrastructure and **smart charging**
- Enhance individual consumer segments with more specific parameters to reflect their **mobility behavior/preferences**

→ Further finetuning necessary before implementing the model extensions in STEM!

Acknowledgement:

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