# Agent-based Simulation of Electric Vehicles

Rashid A. Waraich

Presentation at PSI, September 25th, 2014

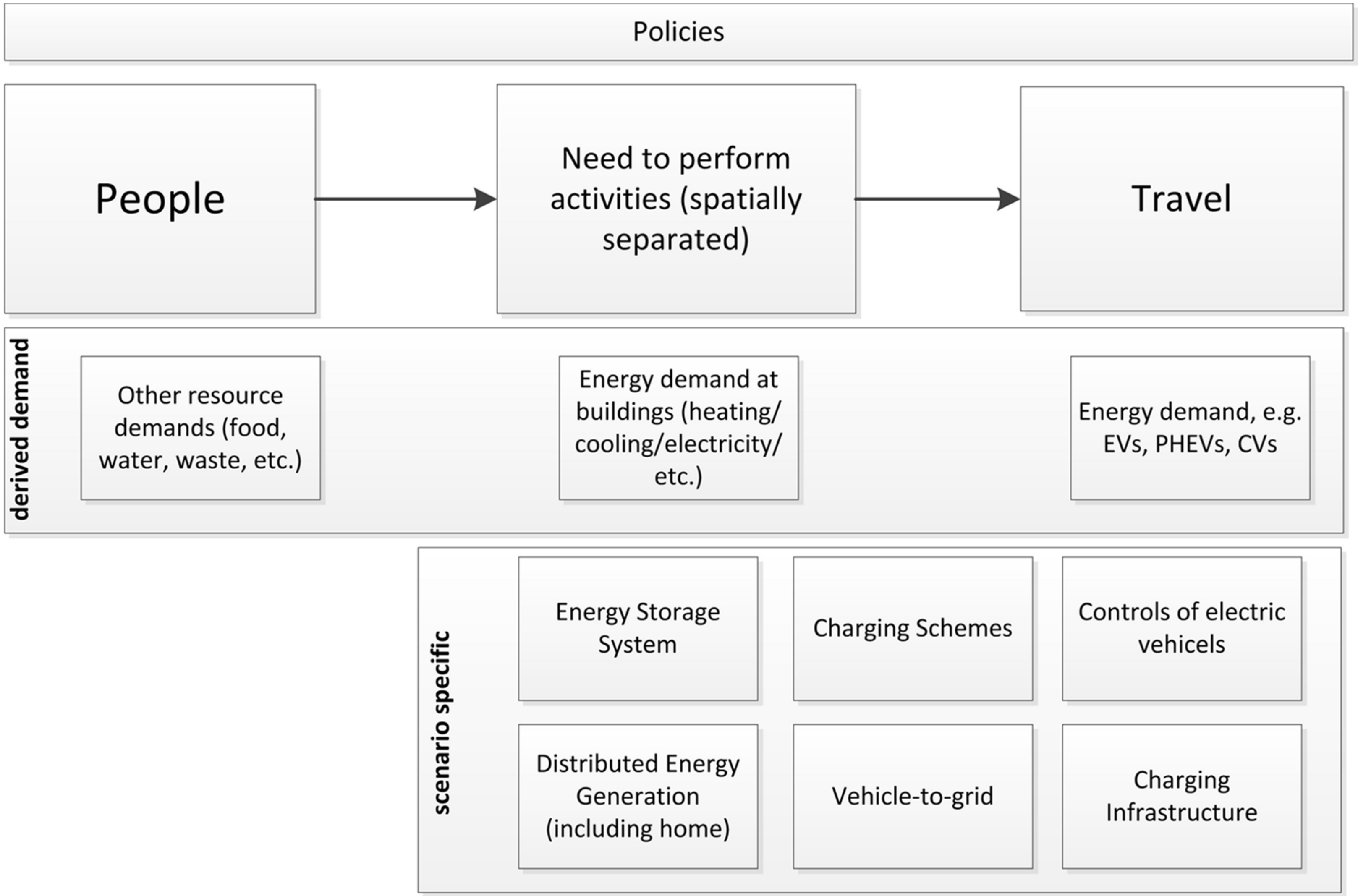
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

IVT Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

# Motivation: Energy Demand Modeling

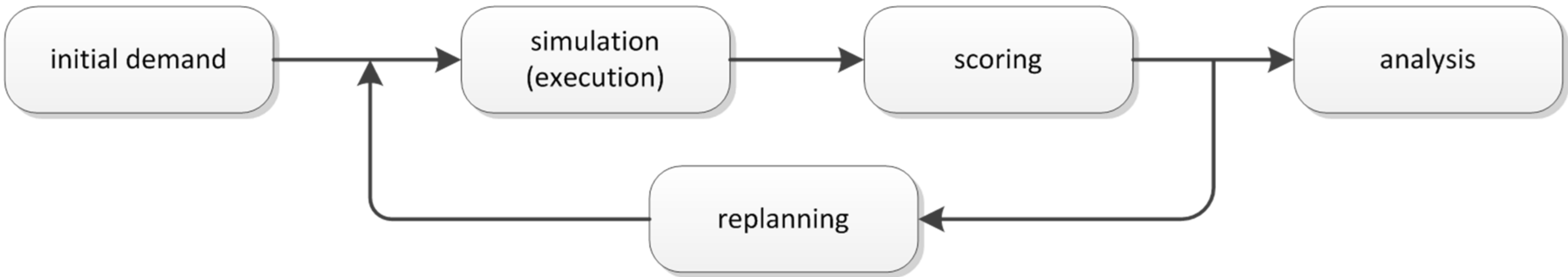
- Case studies integrated modeling of electricity demand and supply related to Evs
  - focus: electricity demand
- Often aggregated models used in this context
  - good for getting an overview of supply and demand
- Disaggregated models needed for uncovering bottlenecks in the electricity network (e.g. power-line constraints and transformer overloads)

# Activity-based Modeling (Bottom-up)

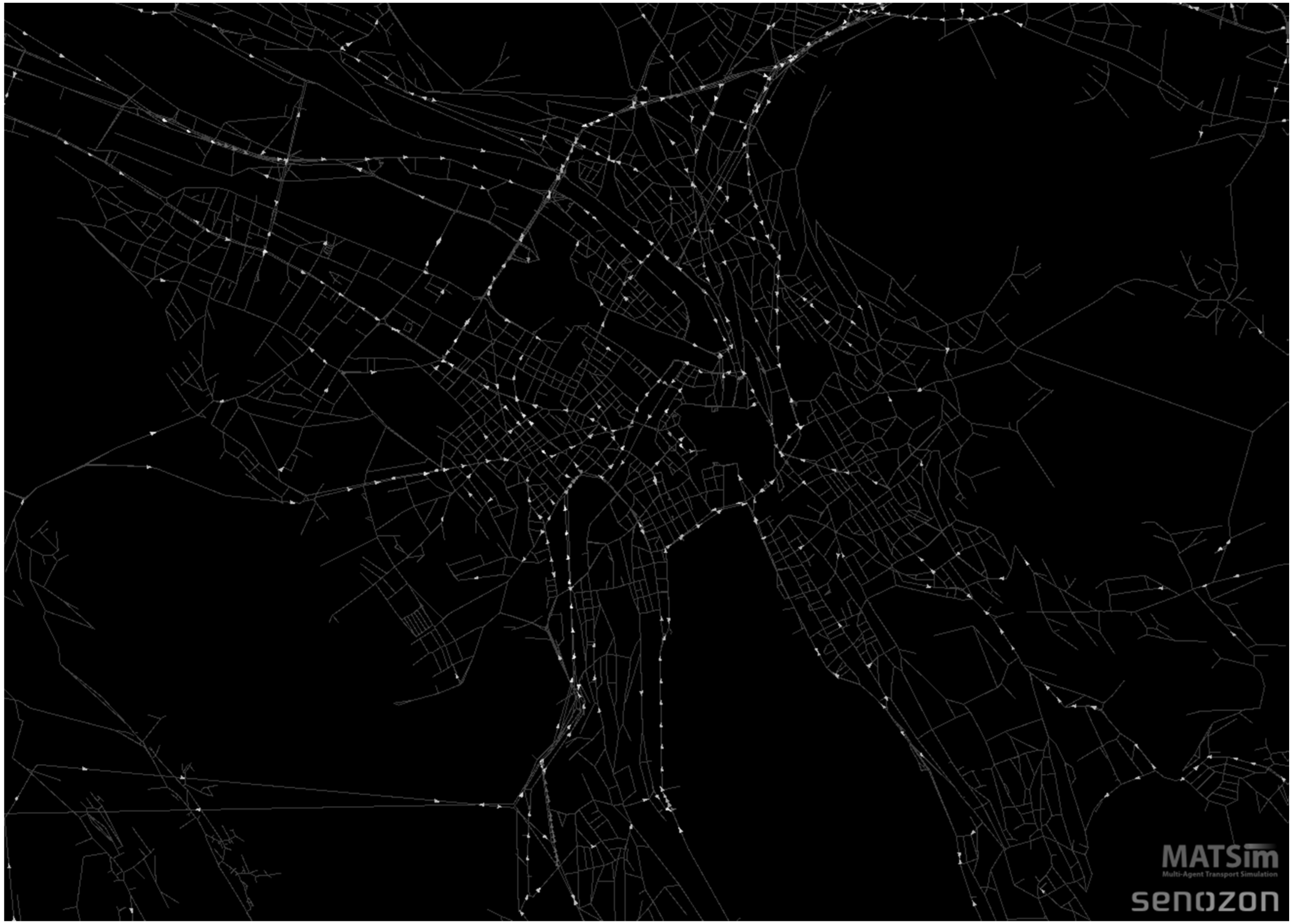


# How do we Model Travel Demand?

- MATSim (open source) – ETH Zurich, TU Berlin
- Synthetic population: people -> agents
- Individual preferences (based on survey data)
- Optimization of activity and travel demand for whole day
- Initial plans based on census data/travel diaries
- Plans contain acitivites (work, shopping, education) and trips
- Several transport modes available (car, walk, public transport and bike)
- First step of optimization: simulation

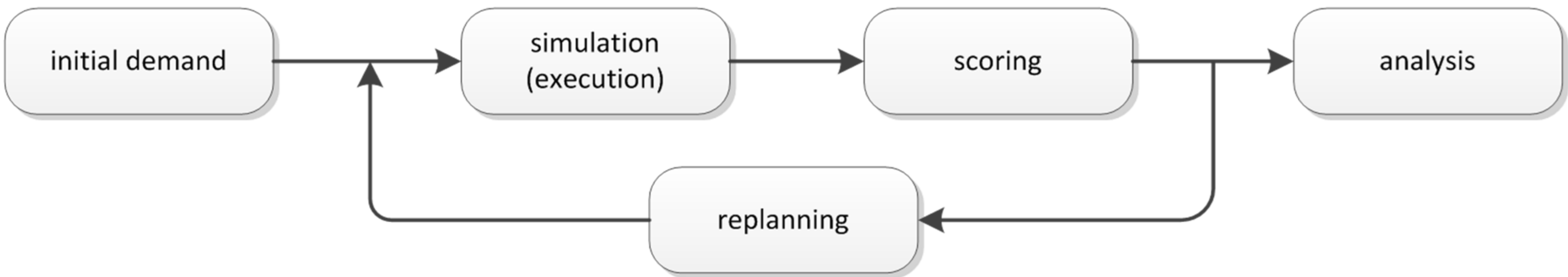


# Simulation



# MATSim

- simulated plans are scored
- Lower travel time and performing activities gives better score
- The goal of each agent is to maximize its score
- Iterative process, based on idea of evolutionary algorithm
- Replanning (change travel mode, route, times, etc.)
- Co-existence of several plans
  - Bad plans deleted over time, good plans have higher chance of getting selected for execution -> survival of the fittest
  - Iteration continues -> optimal plans ("Nash Equilibrium")



# Case Study 1: Berlin Scenario/Test scenario (2009)

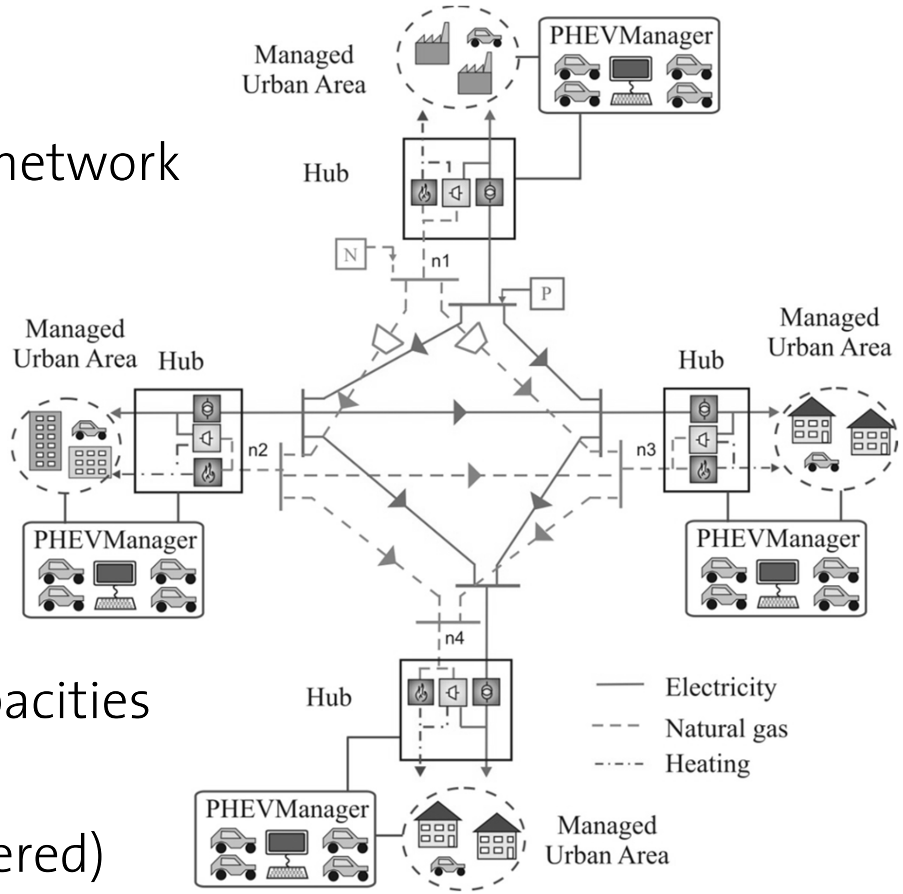
- Goal: Evaluate impact of different charging controls on electricity grid
- Scenario
  - Berlin network
  - 16‘000 agents => 1% population sample
  - Adjusted road network capacities
  - Home-work-home, home-education-home activity chains
  - Charging plugs available at all parking – standard swiss plugs (3.5 kW, 240 V, 16 A, single-phase)
  - PHEVs with 10kWh battery size
  - Energy consumption model: same for all vehicles
  - 4 hubs (arbitrary division of network related to el. grid), base load of a typical western city

# TESF Modules - Charging Schemes

- uncontrolled charging: start charging upon arrival
- Time of use: agents react to prices and try to minimize cost; can be included in utility function of agent
- Controlled/Smart charging
  - goal: avoid bottlenecks in grid (e.g. transformer/ power-line overloads)
  - tried with two different levels of information/flexibility in separate case studies:
    - Knowledge about how long planned to stay parked + future planned trips and charging possibilities of day ("max. possible knowledge/flexibility")
    - Knowledge about how long planned to stay parked and desired charge when leaving
    - Energy markets

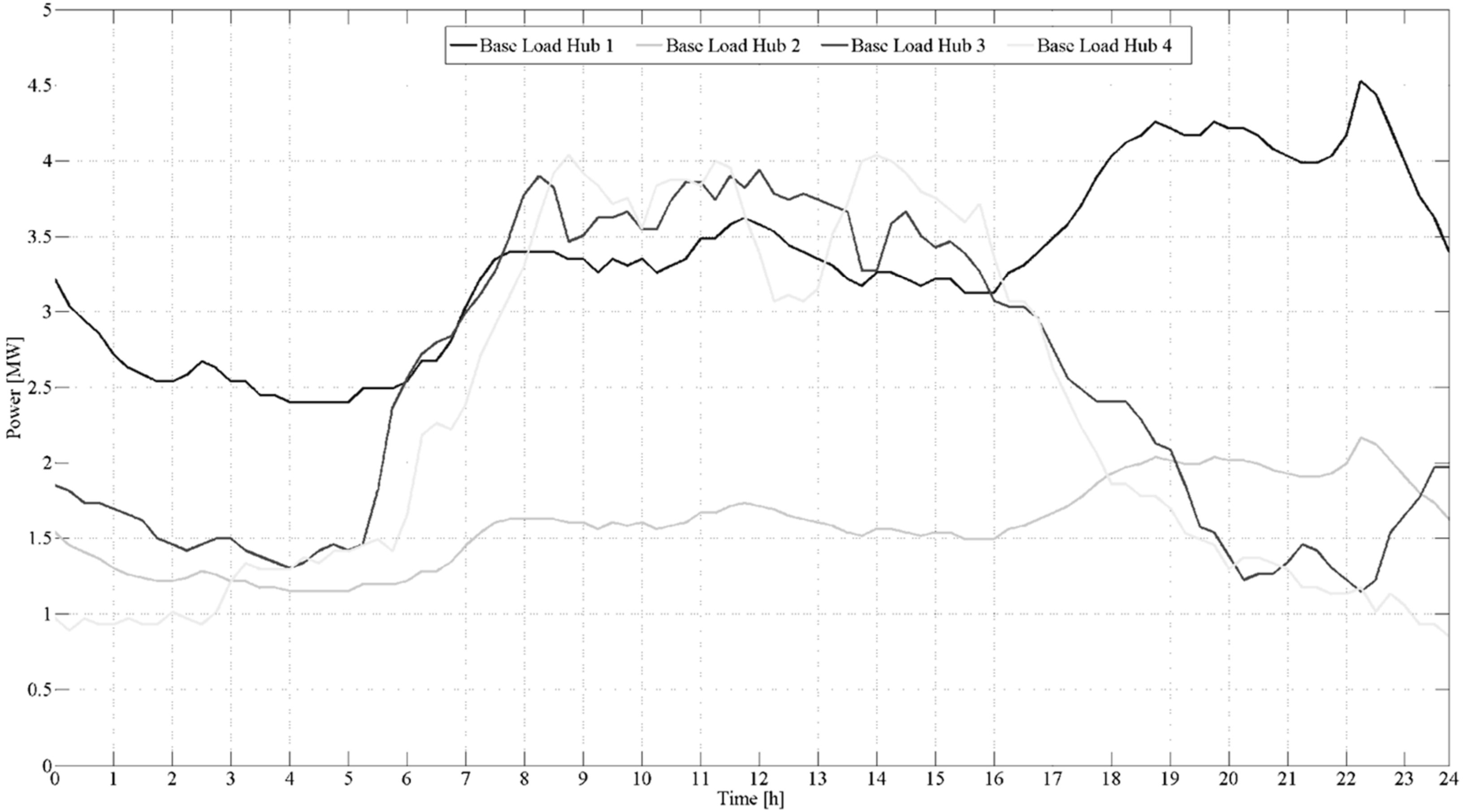
# PEV Management and Power System Simulation (PMPSS)

- Each hub models an urban area; each hub contains furnace for meeting heat demand; transformer for el. supply.
- A small combined heat and power turbine (CHP)
- CHP interconnects el. and gas network
- can relieve el. networks




only the transformer and CHP capacities are considered as limiting factors
(power line capacities not considered)

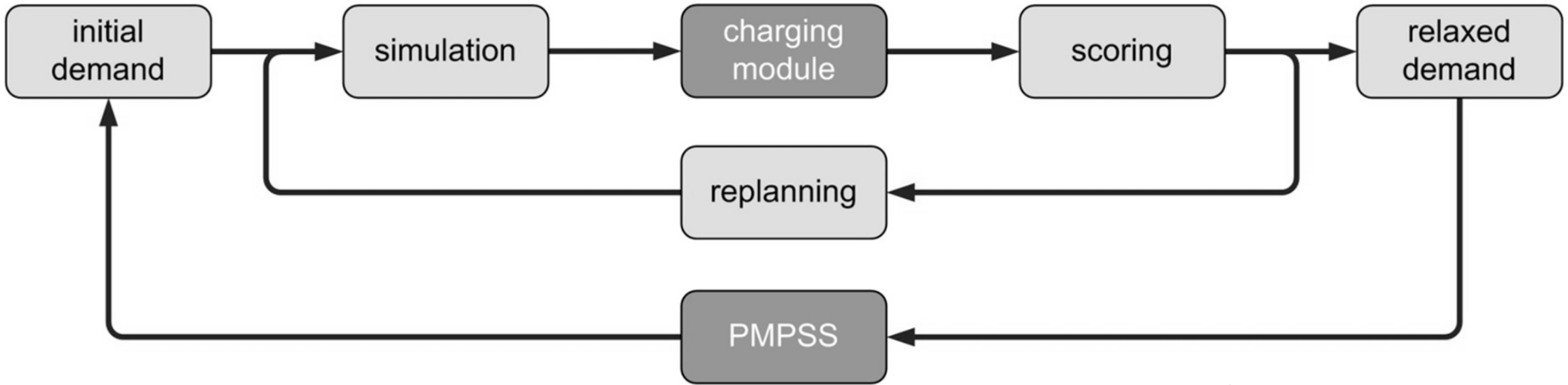
# Base load curve at the 4 hubs (non-EV load)




The maximum power input, e.g., transformer capacity ratings for hubs 1–4 is defined as 9 MW, 4.4 MW, 8 MW and 8.2 MW, respectively

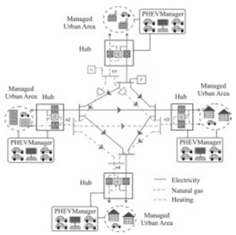
# Simulating EVs/PHEVs in MATSim

+ energy consumption
model, fleet definition

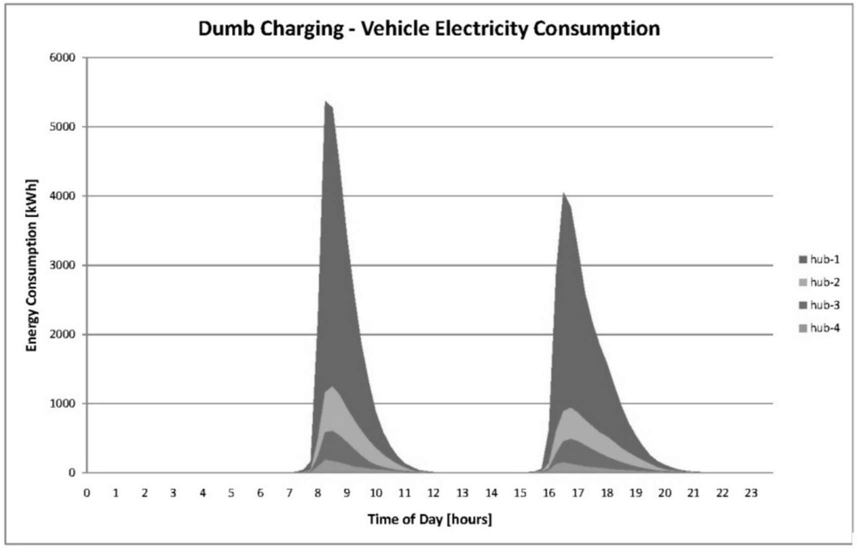


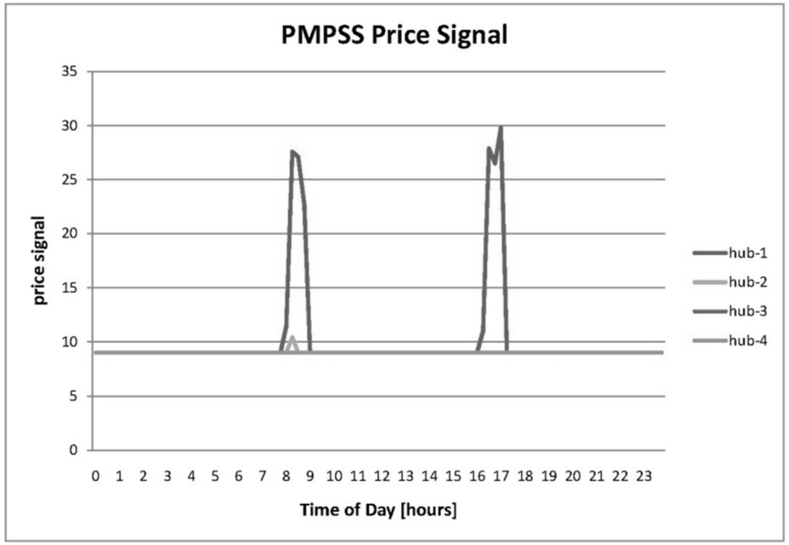

grid constraint violations?
=> In case of controlled charging,
try to adapt demand

charging information (time, location)

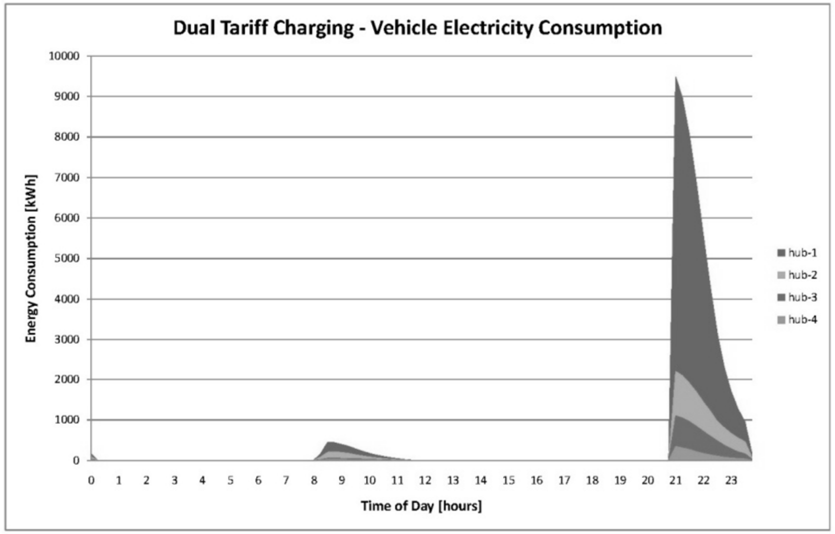


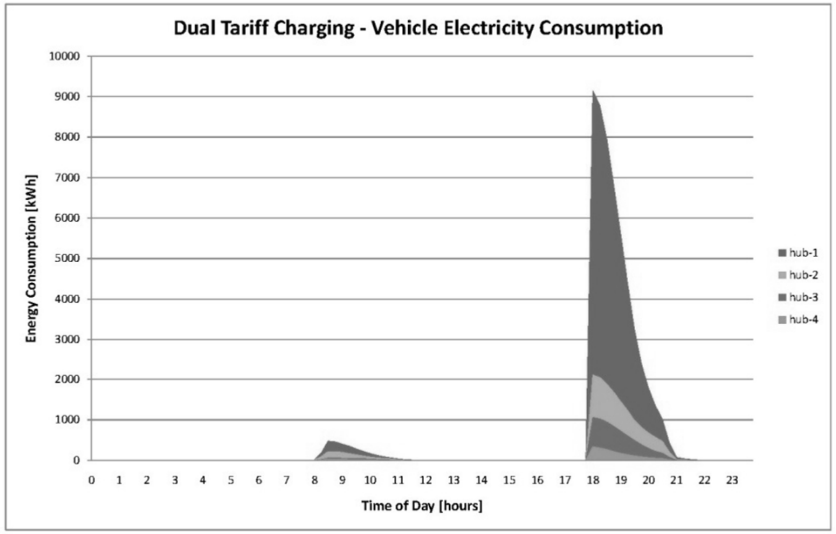
# Uncontrolled Charging: Start Charging at Arrival



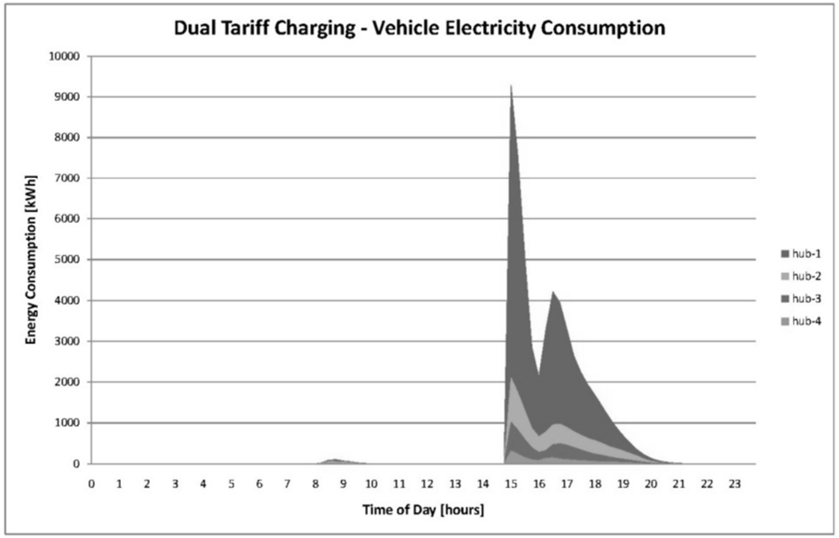
# Time of Use Charging: Dual Tariff



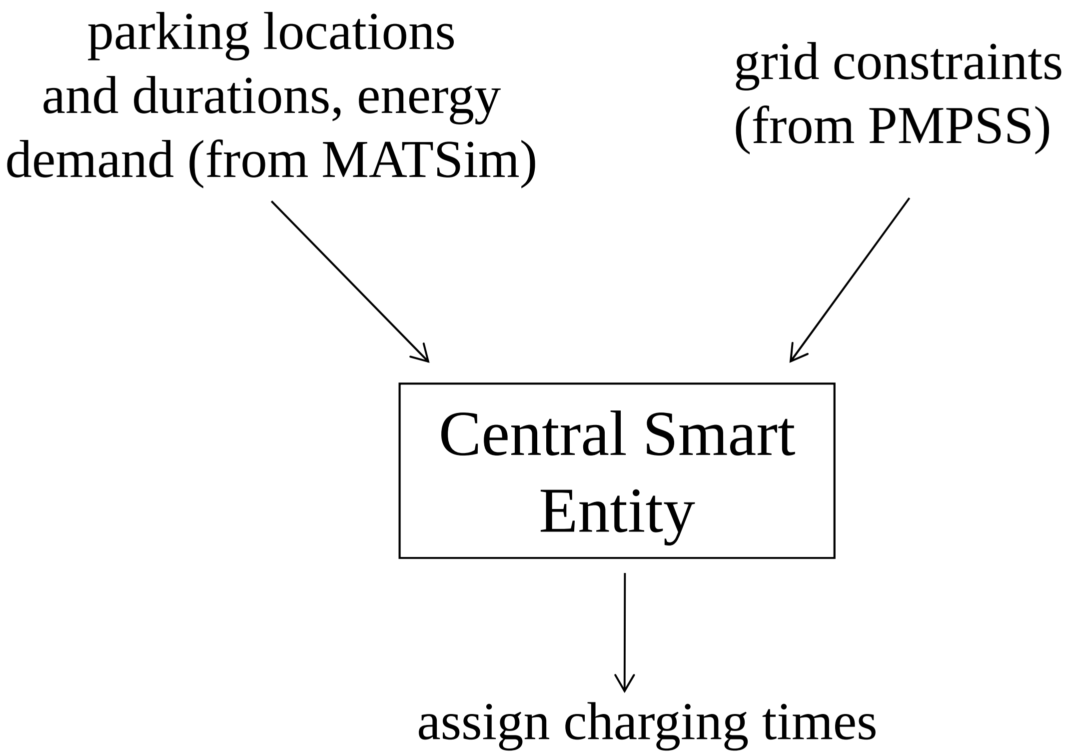

Low: 9pm – 5am

Low: 6pm – 5am



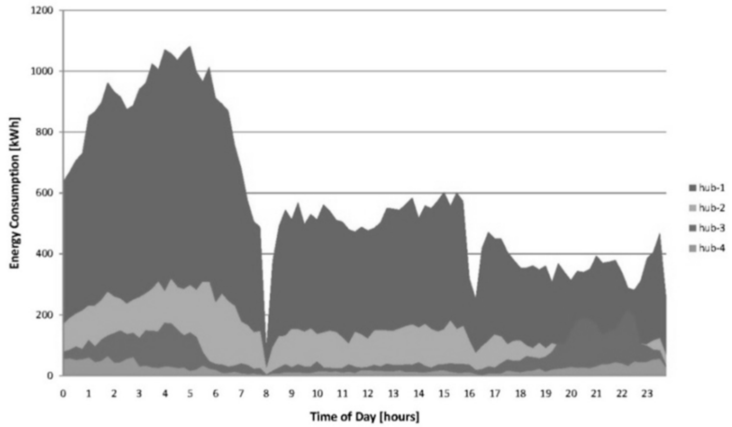

Low: 3pm – 5am

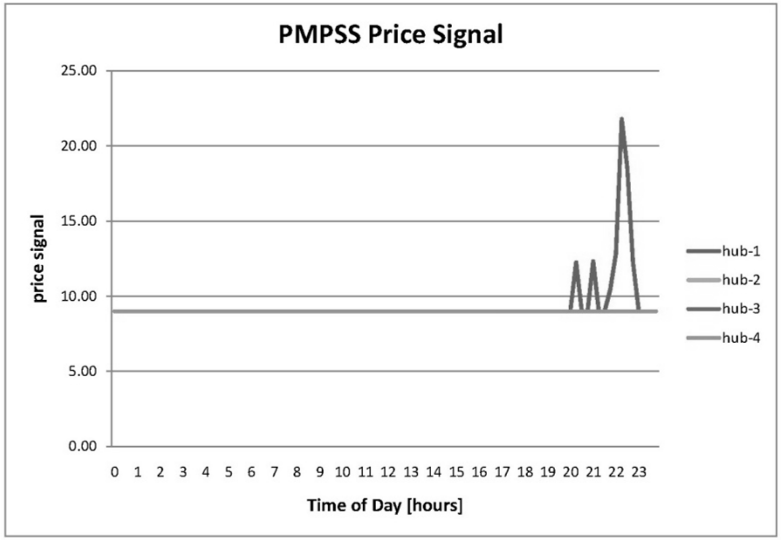
# Centralized Smart Charging



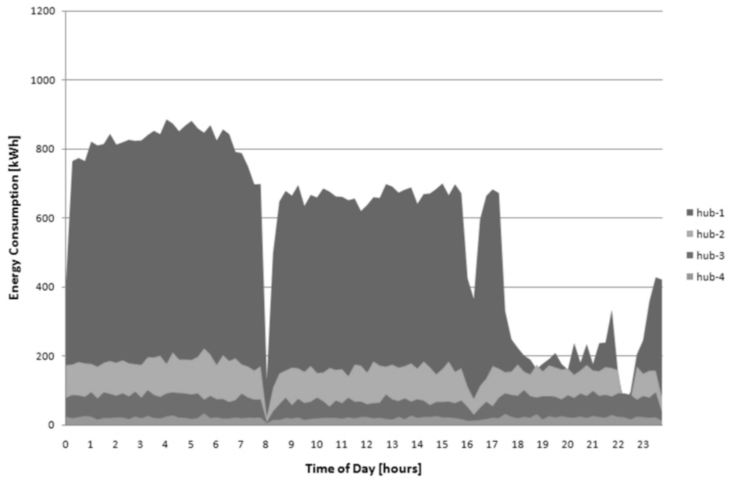
# Centralized Smart Charging

1. Iteration – grid contraints violated




5. Iteration – all vehicles charged successfully



# Case Study 2: Real World Scenario for EWZ (2011)

ETH-LAV

Prof. Boulouchos

Dr. F. Noembrini

G. Georges

LAV
Laboratorium für Aerothermochemie und Verbrennungssysteme
Aerothermochemistry and Combustion Systems Laboratory

ETH-PSL

Prof. Andersson

M. D. Galus

eeh power systems laboratory

ETH-IVT

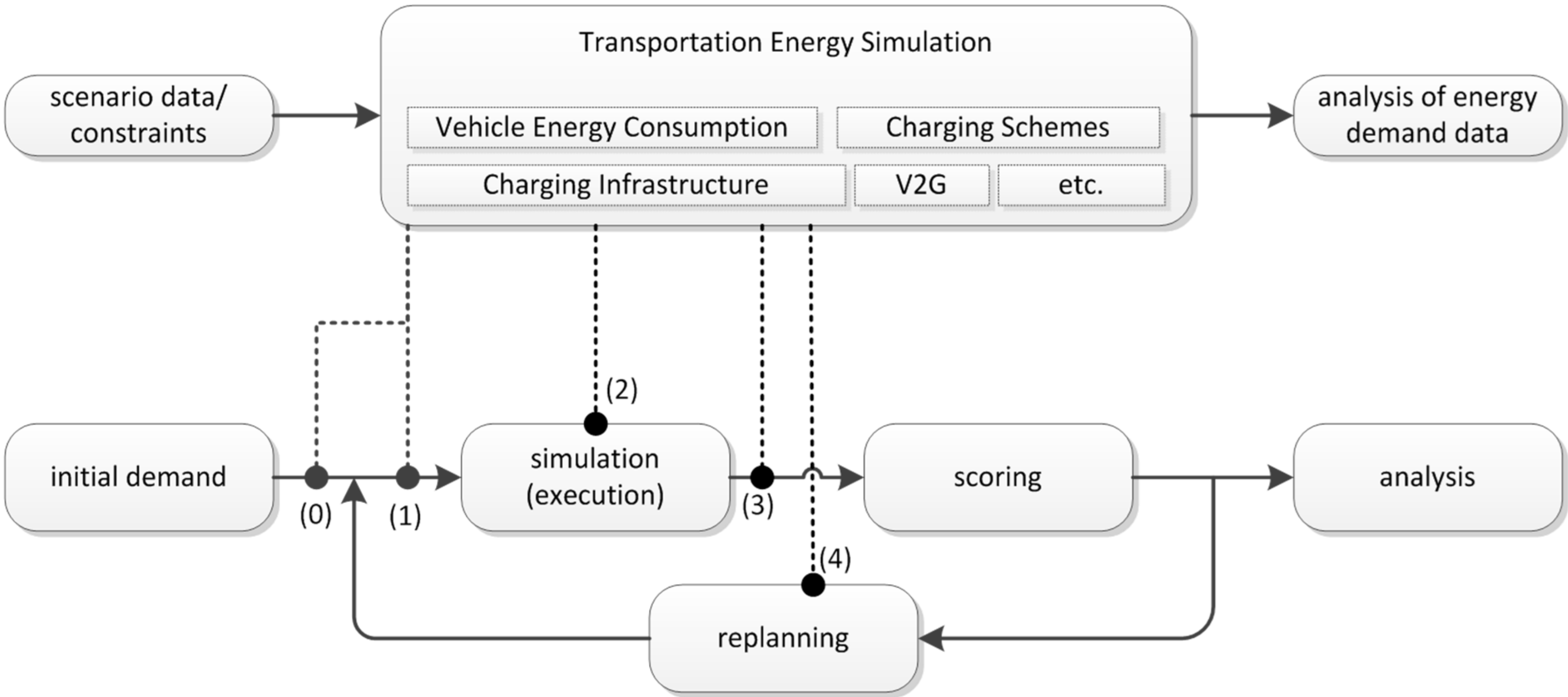
Prof. Axhausen

R. A. Waraich

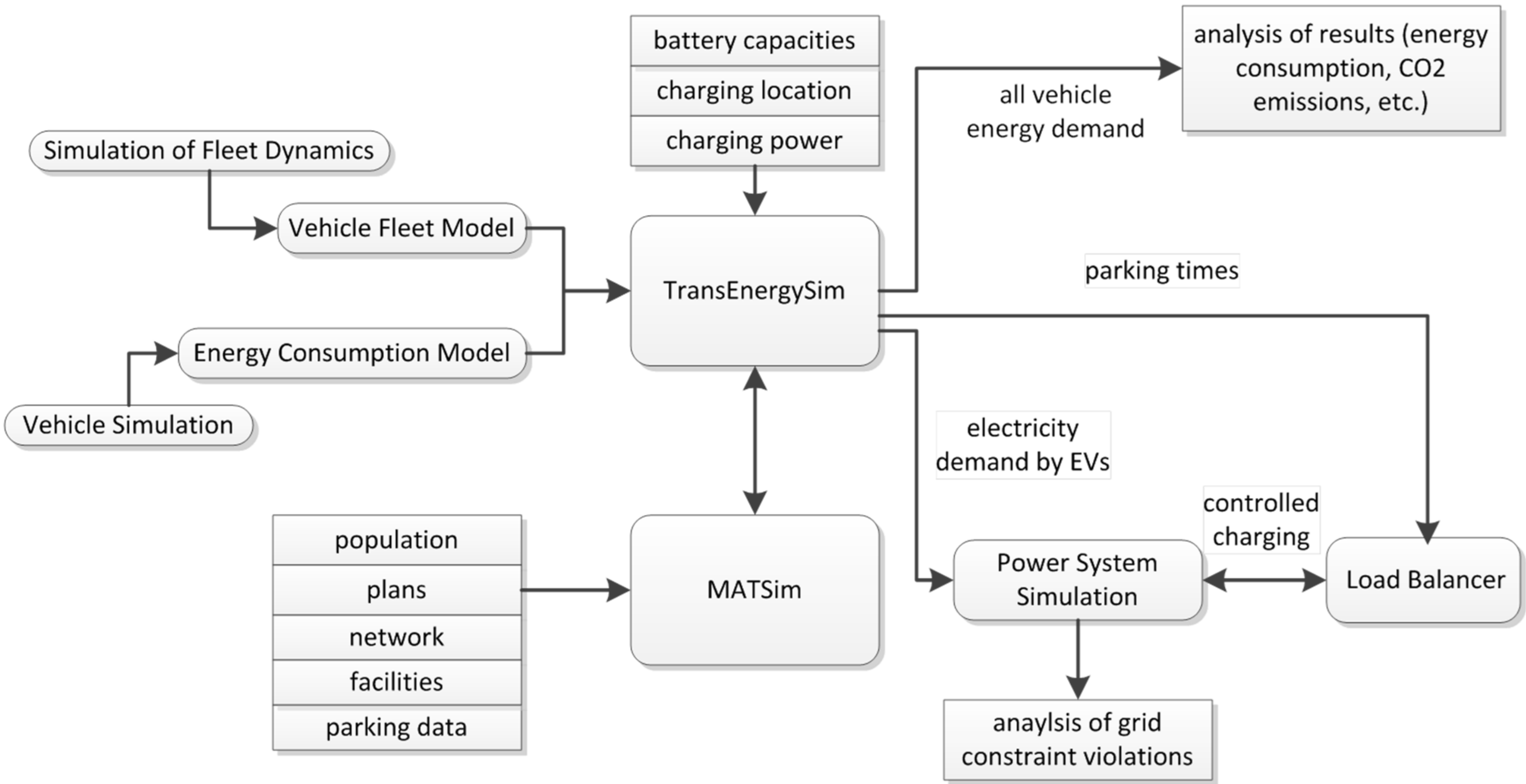
IVT Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

[Source: Around 50% of presentation content is based on ARTEMIS project presentation, December 2011]

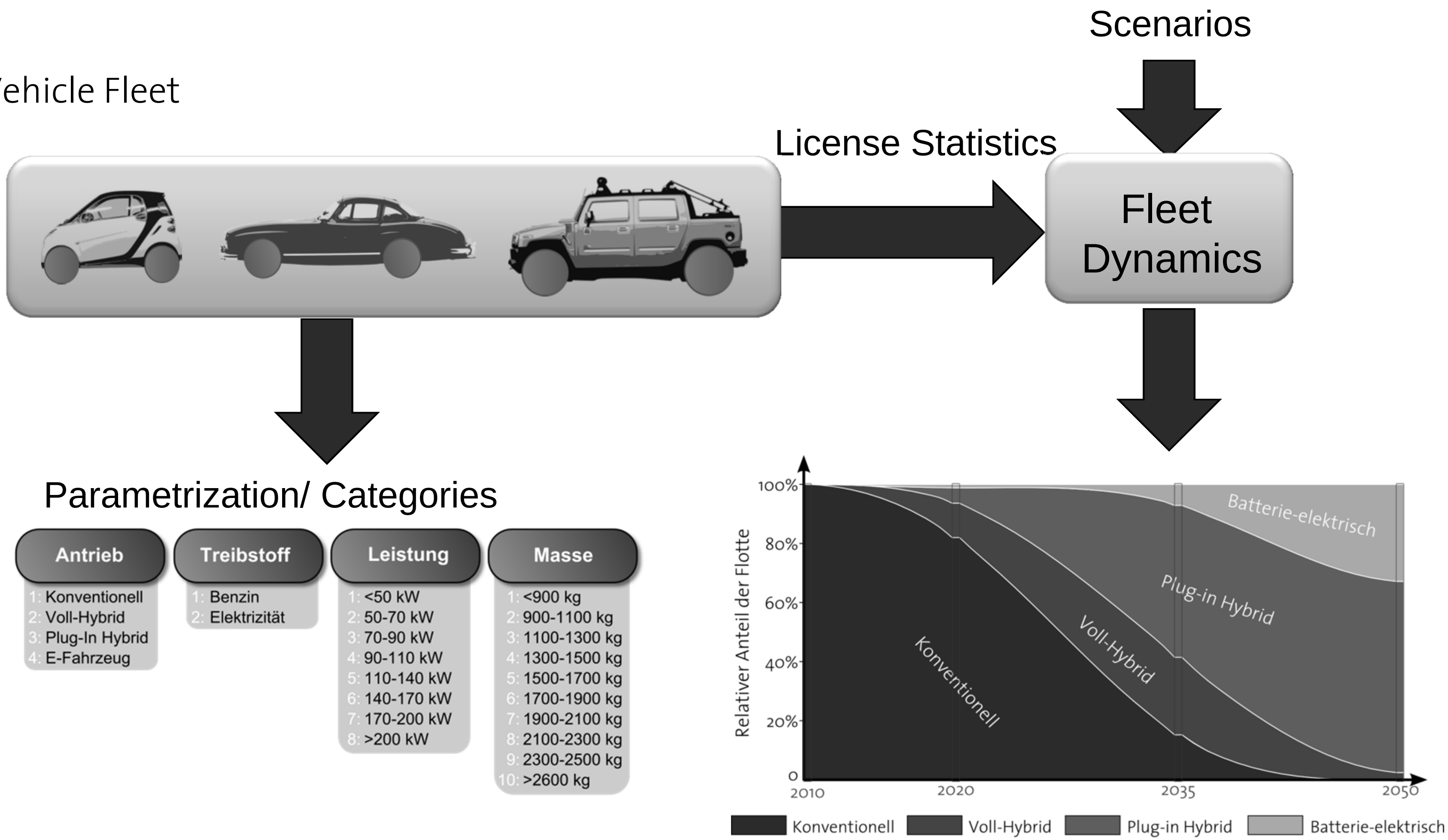
# Transportation Energy Simulation Framework (TESF)



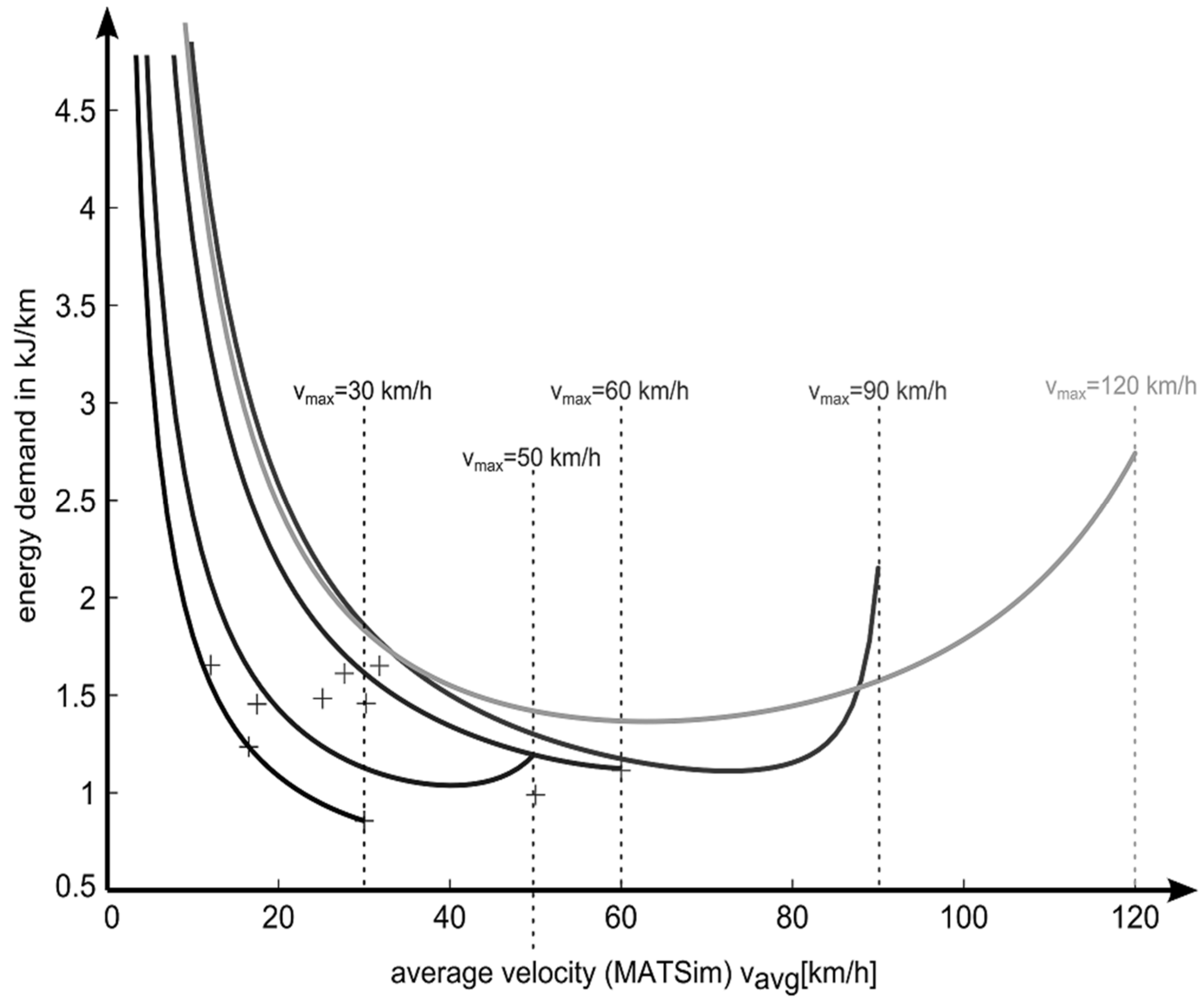
# System Overview



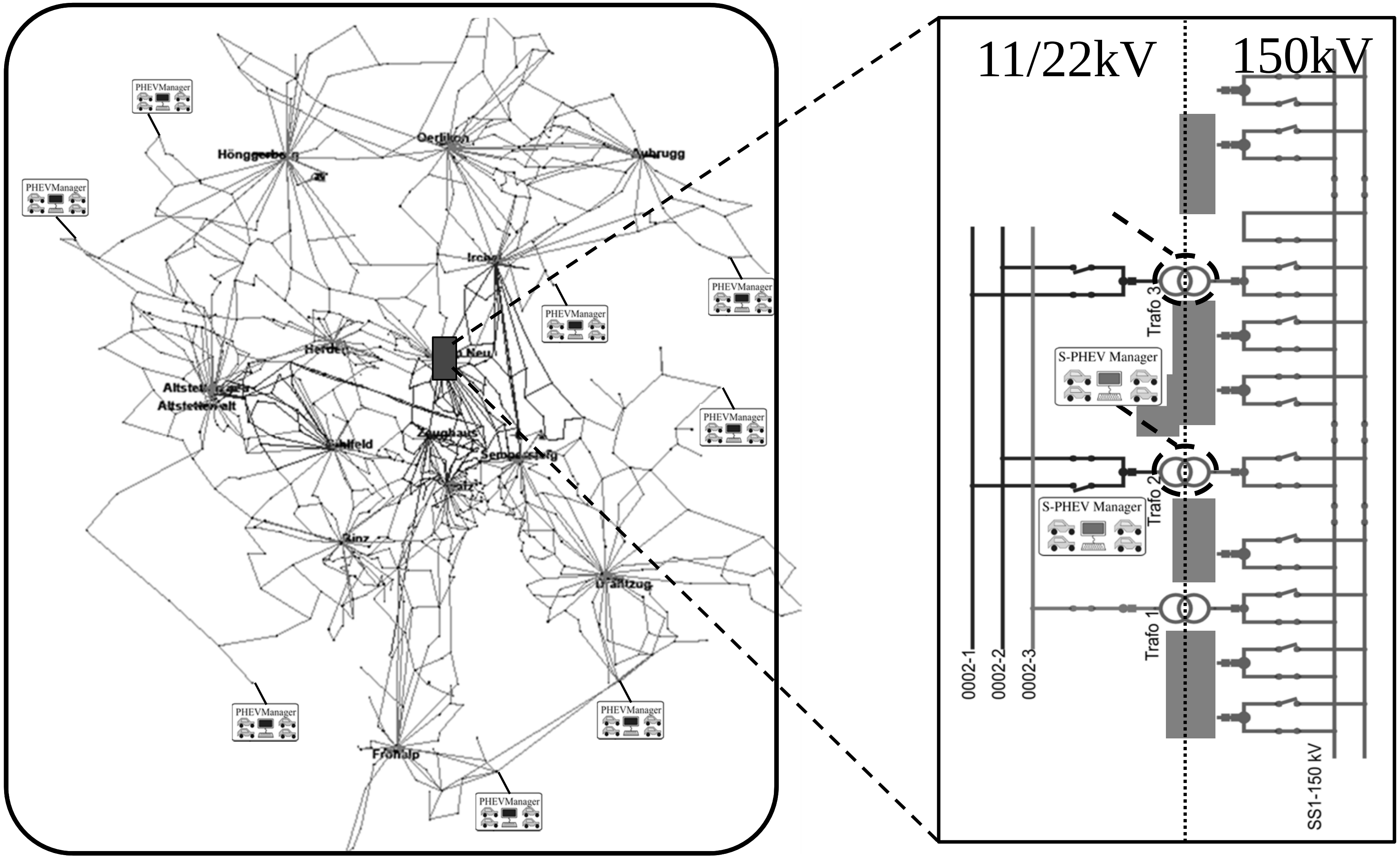
# Fleet Dynamics



# Energy Consumption Regression Model (con’d)

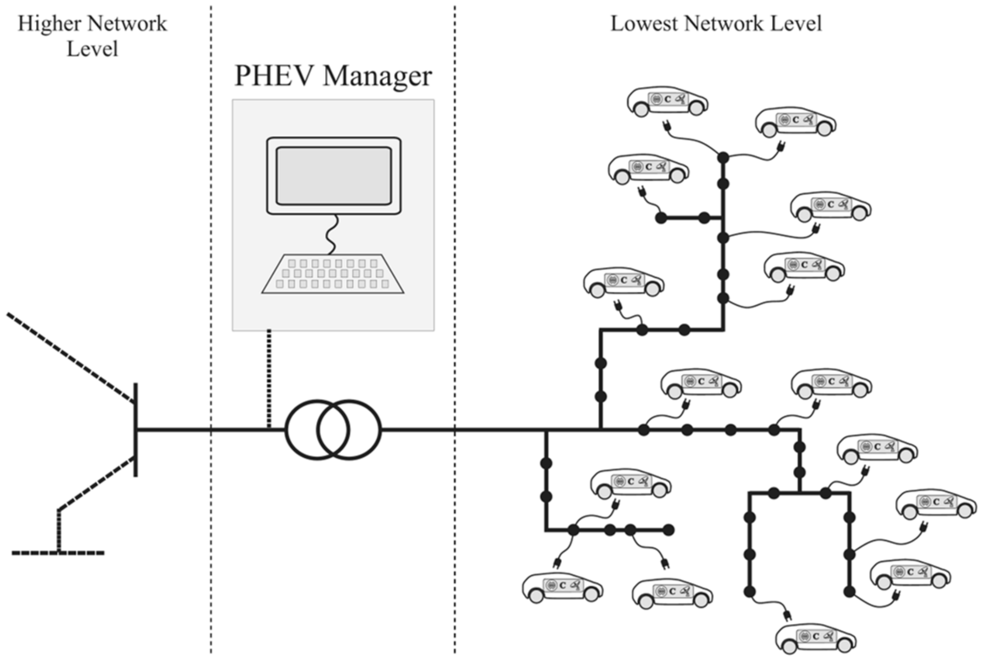


# Power System Simulation and Load Balancing



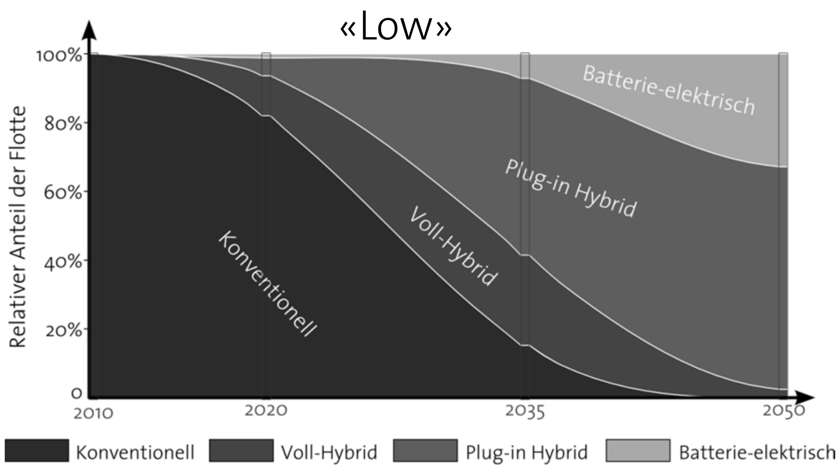
# Power System Simulation and Load Balancing (con'd)

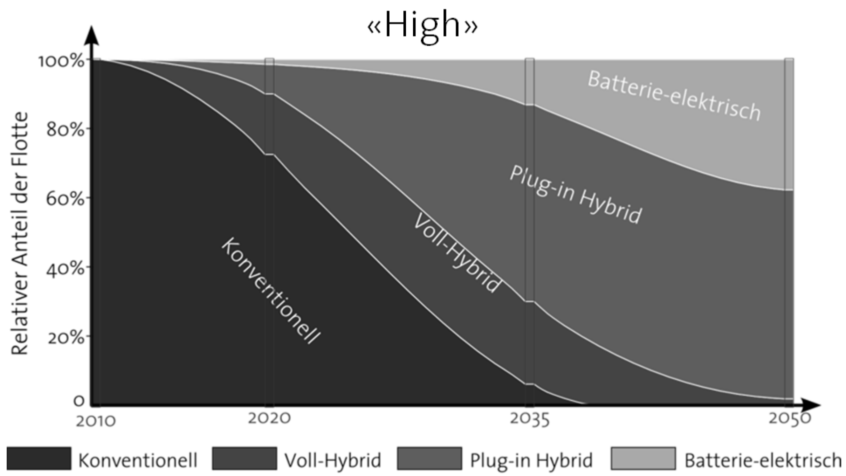
- Parking assigned to closest medium voltage node (11/22 kV)
- Controlled charging tries to avoid overload of transformers and power lines, while usage flexibility of charging (only parking duration)
- Optimizations every 15min



# Scenario Parameters

## ➊Fleet Composition



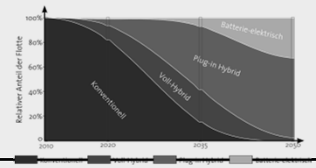
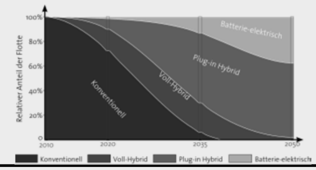
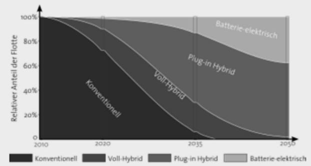

## ➋ Charging Infrastructure:

- Availability: home | work | everywhere
- Charging power: 3.5 kW | 11 kW

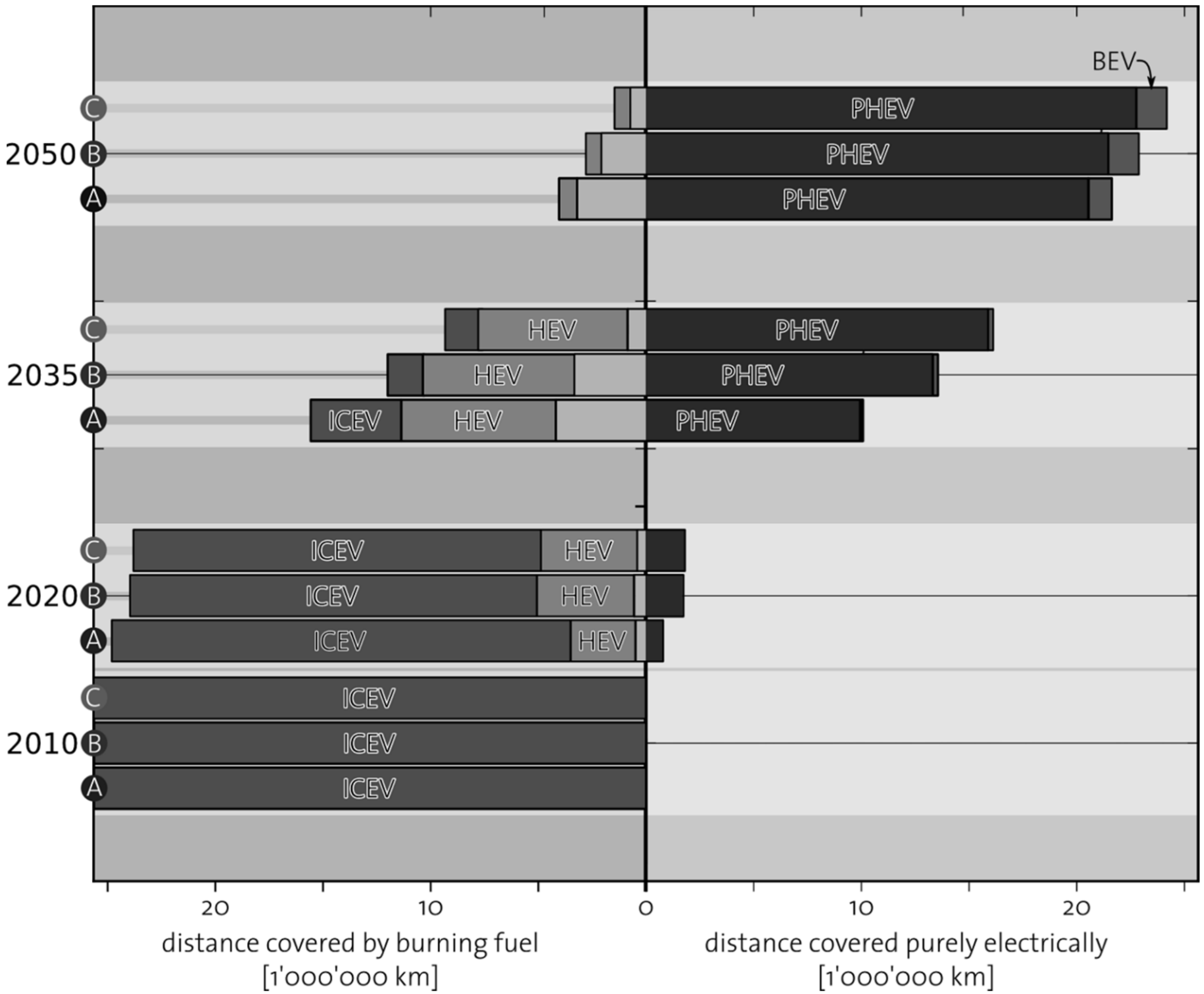
## ➌ Improvement of Vehicle Technology

- Battery size
- Improved energy efficiency

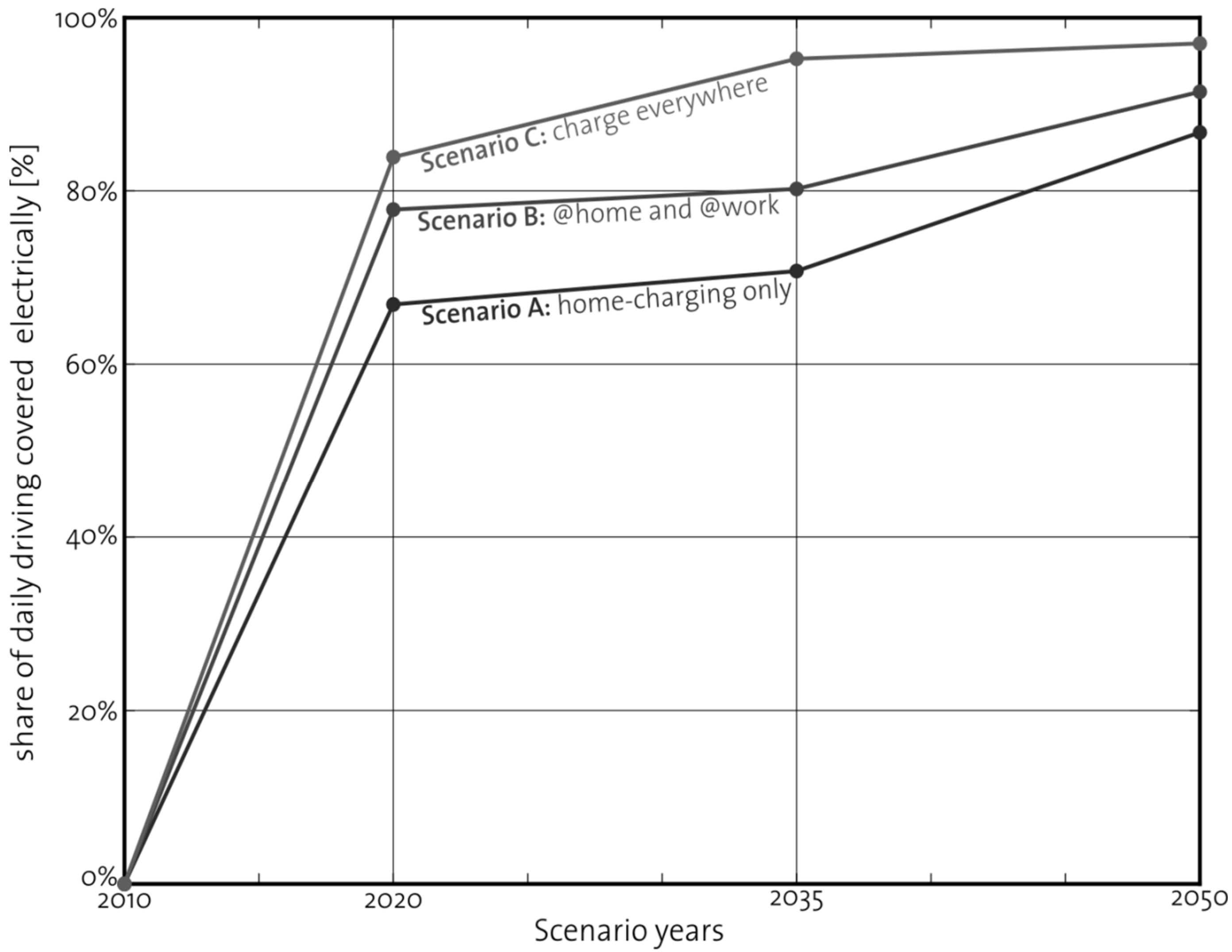
# Overview: Scenarios

| | Year | ❶ Fleet Composition | ❷ Charging Infrastructure | | | ❸ Range |
|---|---|---|---|---|---|---|
| | | | home | work | other locations | |
| Scenario A: «Low» | 2010 | low | / | / | / | *(no EVs/PHEVs)* |
| | 2020 |  | 3.5 kW | / | / | 80 km |
| | 2035 | | 3.5 kW | / | / | 80 km |
| | 2050 | | 3.5 kW | / | / | 150 km |
| | | | | | | |
| Scenario B: «Medium» | 2010 | high | / | / | / | *(no EVs/PHEVs)* |
| | 2020 |  | 3.5 kW | 11 kW | / | 80 km |
| | 2035 | | 3.5 kW | 11 kW | / | 80 km |
| | 2050 | | 3.5 kW | 11 kW | / | 150 km |
| | | | | | | |
| Scenario C: «High» | 2010 | high | / | / | / | *(no EVs/PHEVs)* |
| | 2020 |  | 3.5 kW | 3.5 kW | 3.5 kW | 80 km |
| | 2035 | | 11 kW | 11 kW | 11 kW | 80 km |
| | 2050 | | 11 kW | 11 kW | 11 kW | 150 km |

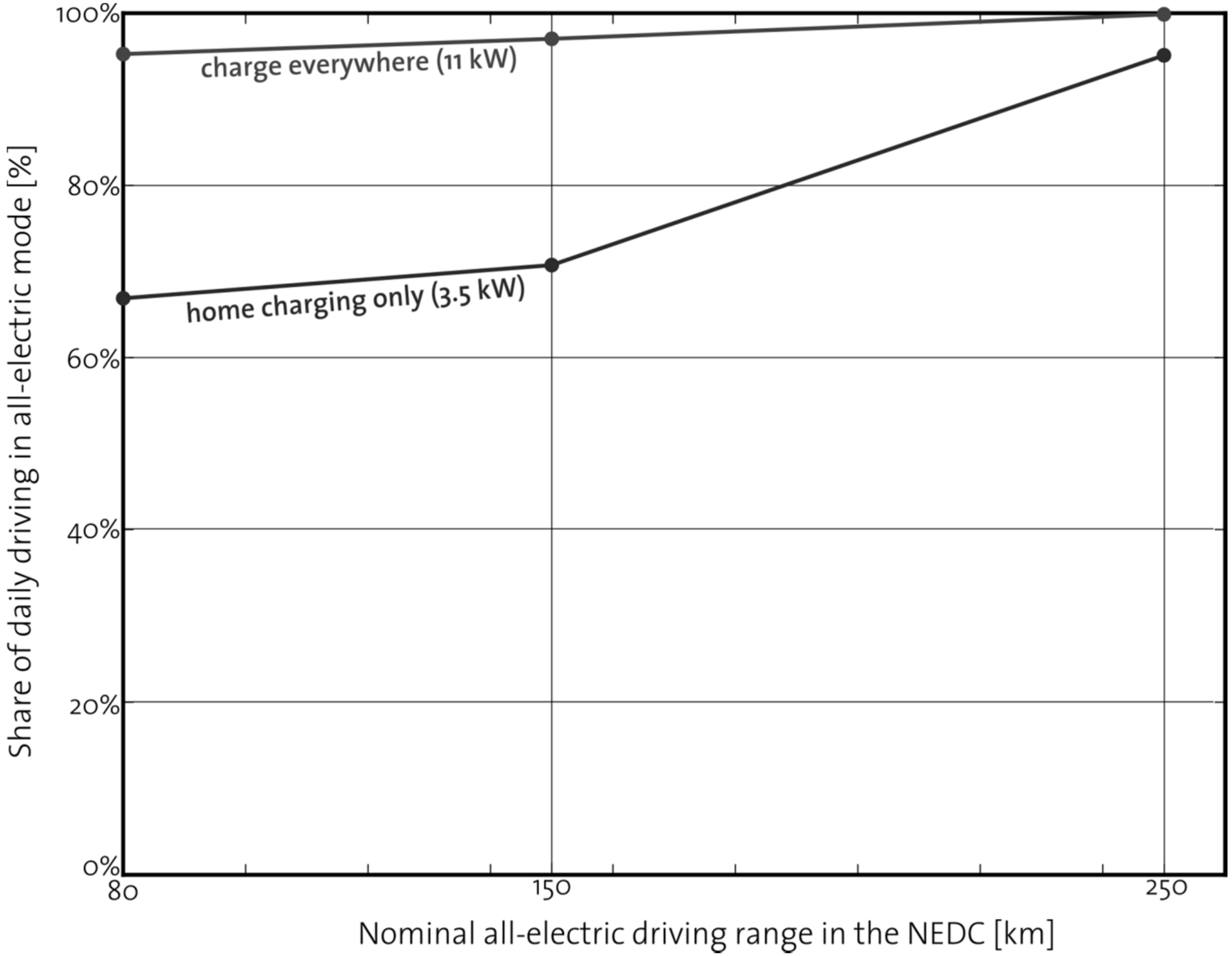
# Distance Travelled



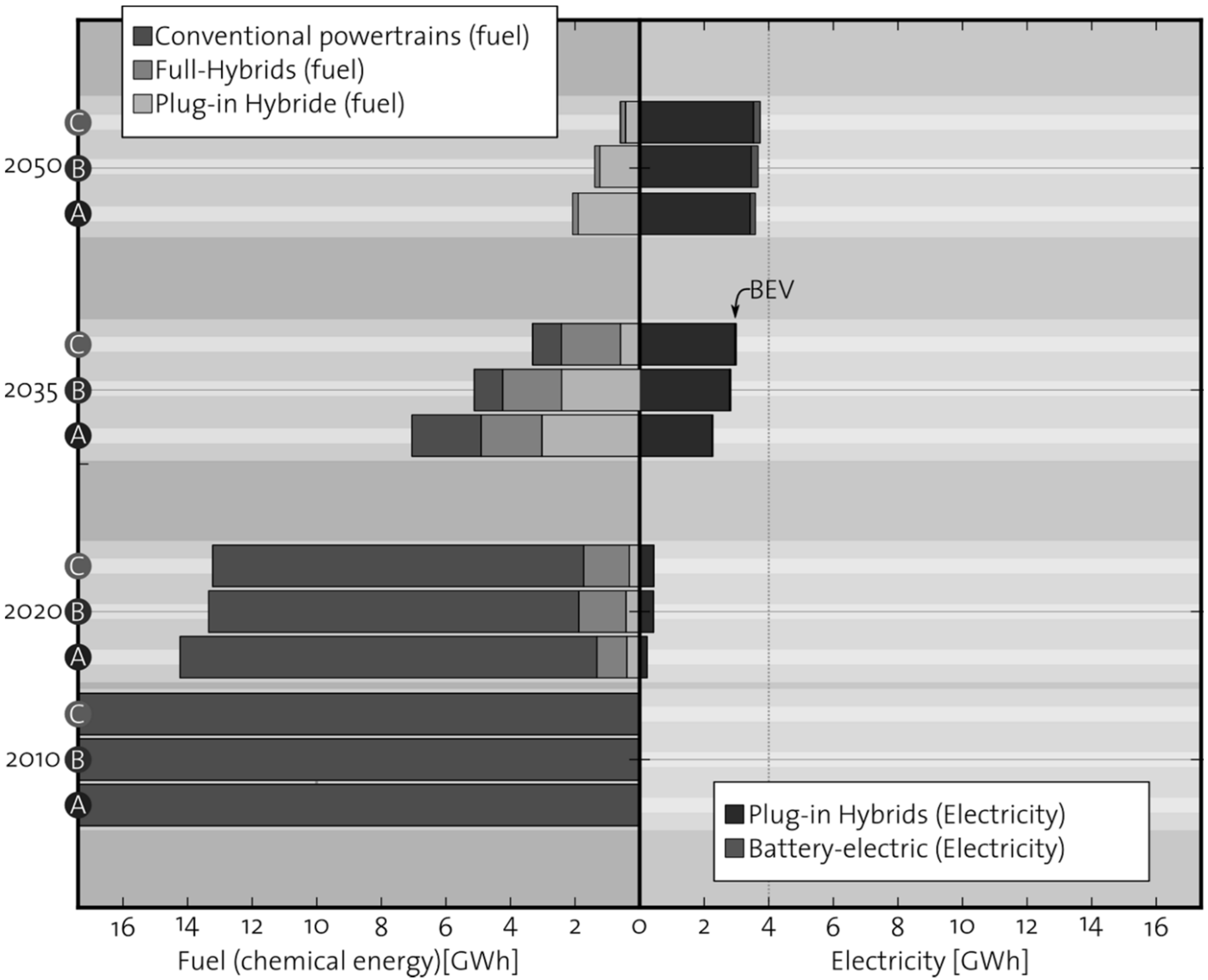
# PHEVs: Electric Drive



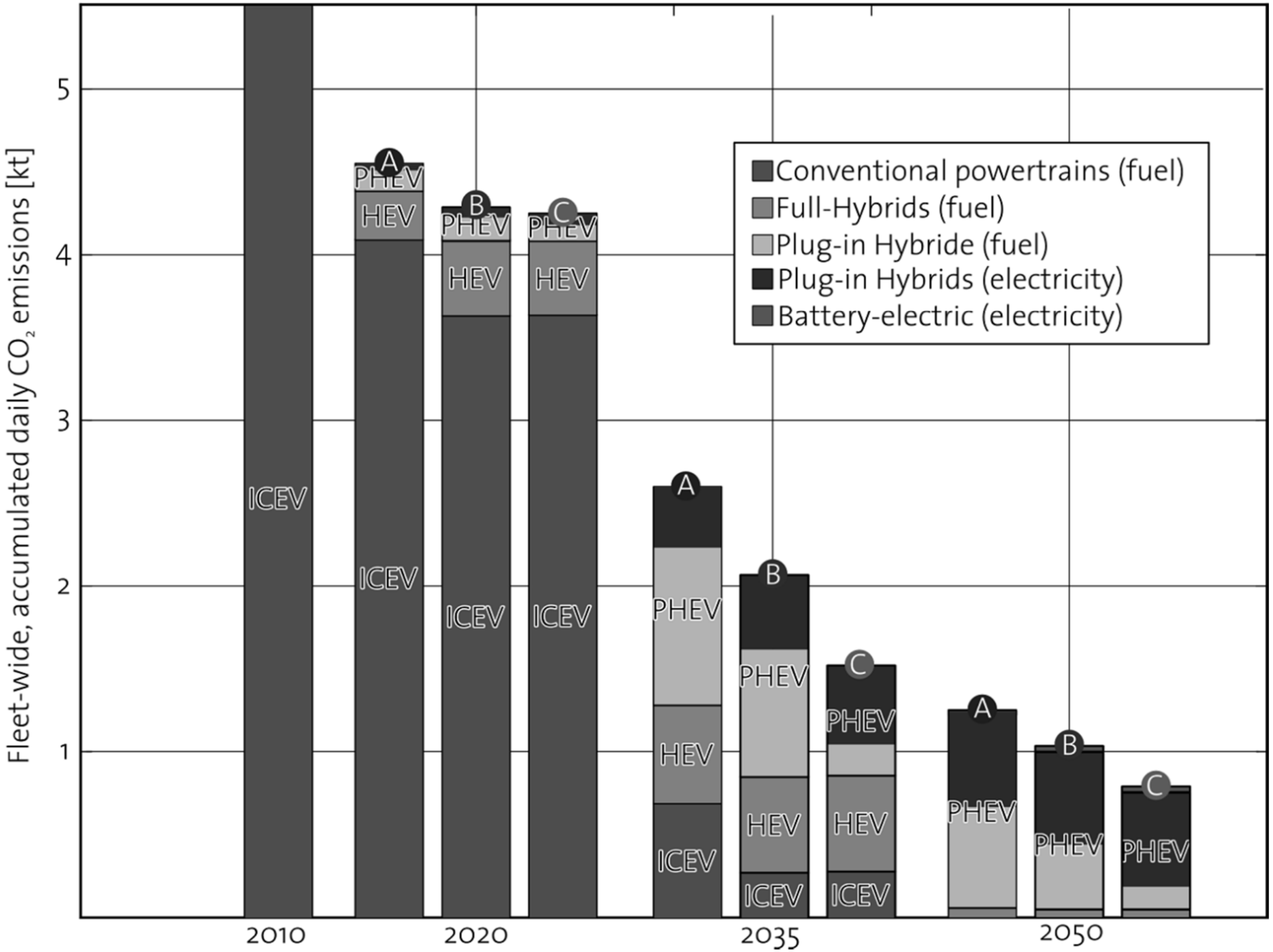
# PHEVs: Electric Drive (Battery Size vs. Charging Availability)



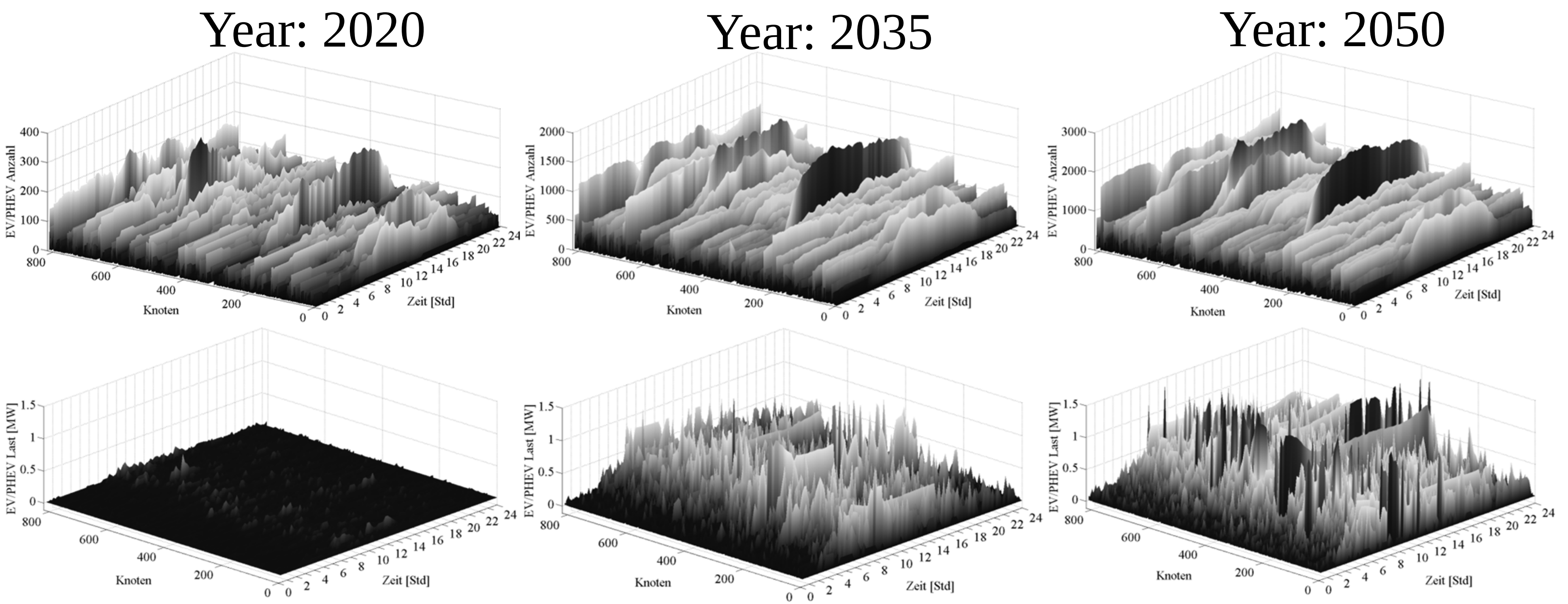
# Energy Demand



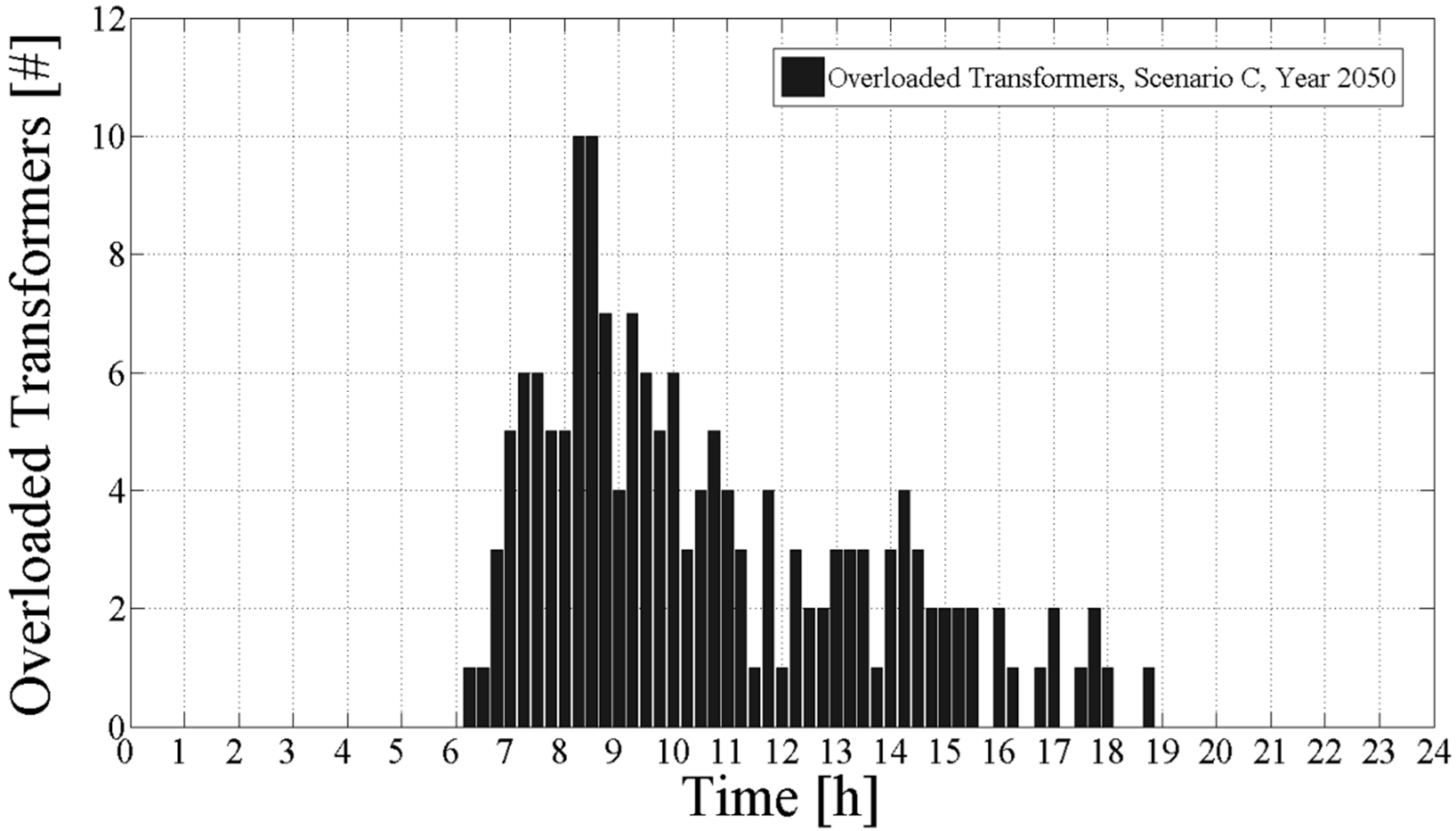
# CO2 Emissons



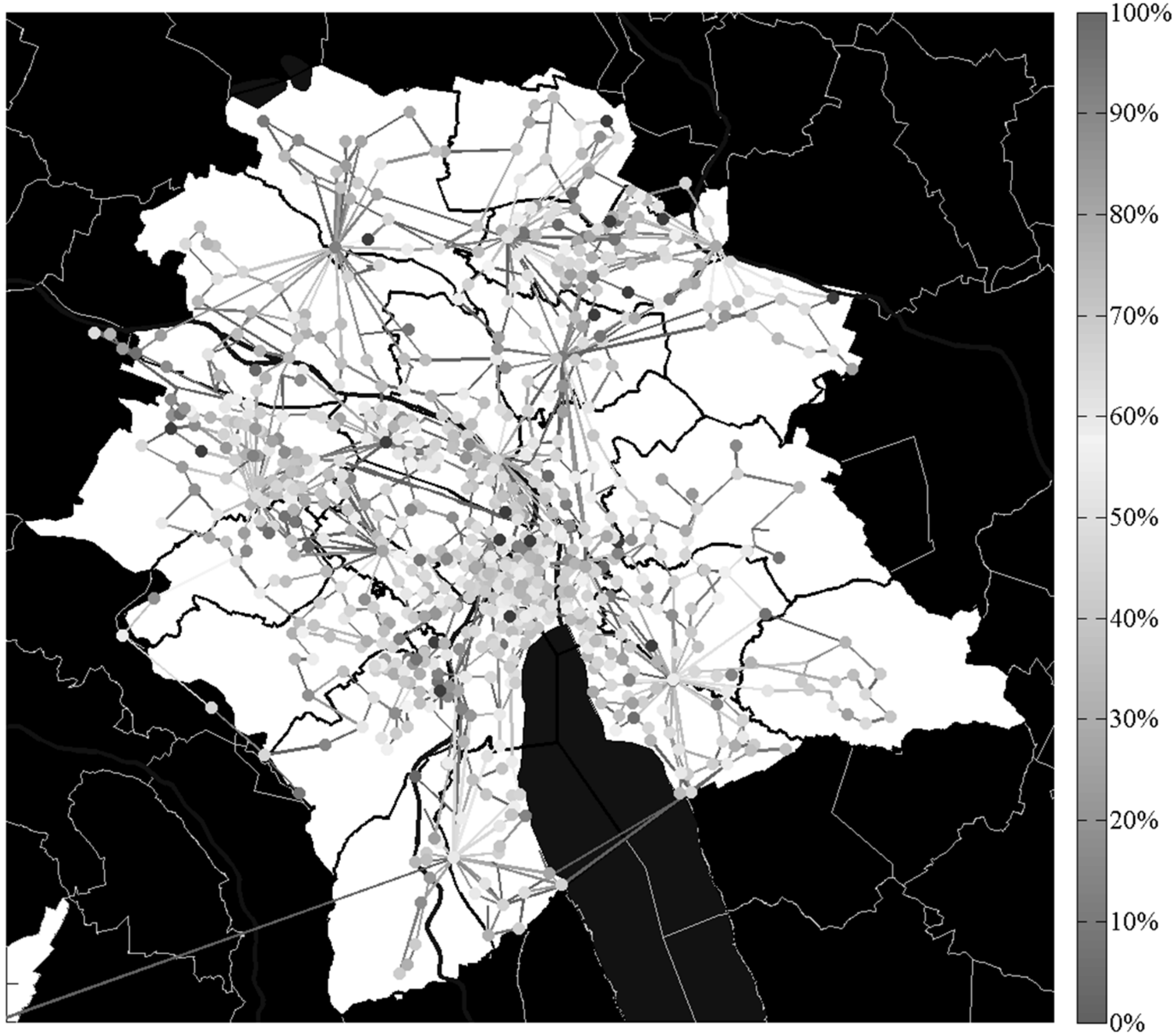
# Results: Electricity Network, Scenario C



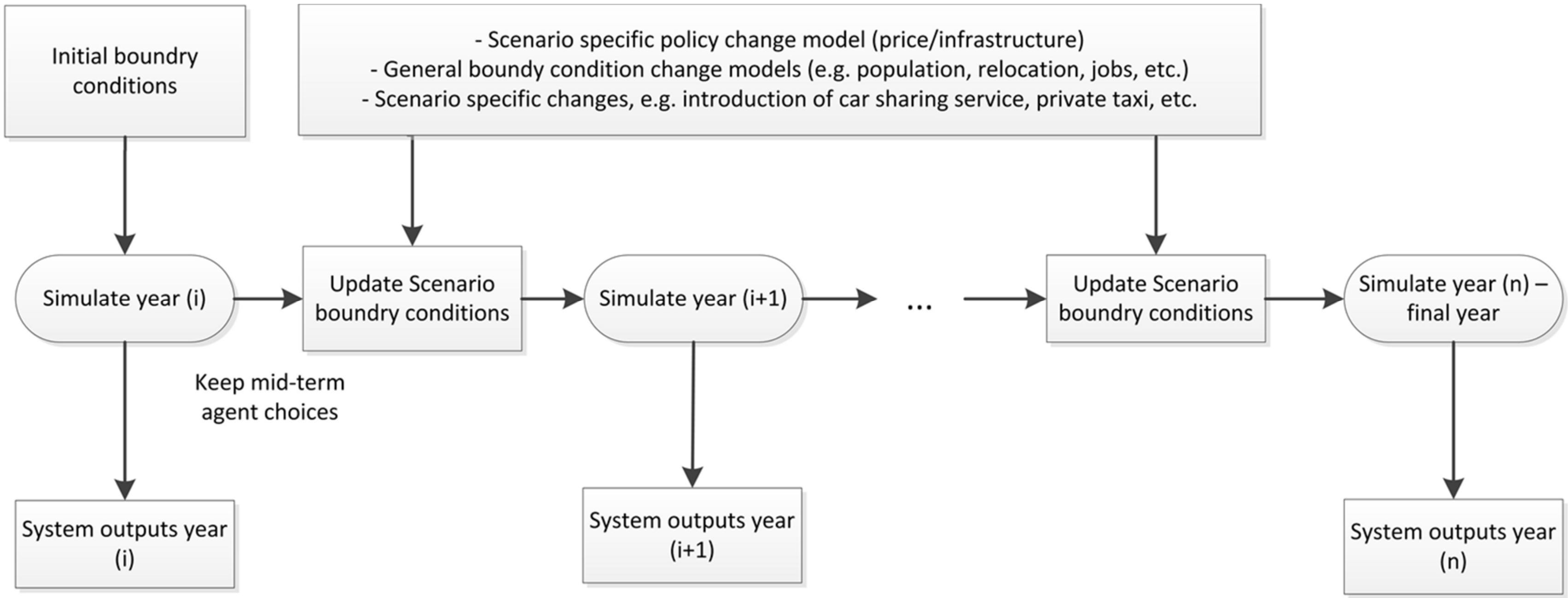
# Scenario C, 2050: Number of Overloaded Transformers



# Snapshot of Resource Utilization at 10 a.m. (Scenario C, 2050)



# Current Research: Policy Design & Evaluation



# Simple example: EV Car share

Interaction between

Interaction of subsidies for EVs: batteries, free parking

and

taxes for CVs: vehicle tax, fuel tax, higher road pricing, parking cost, etc.

# Outputs

- Policy Evaluation/Performance – including price incentives and Infrastructure change
  - ⇒ Find possible “Hidden” side effects
  - ⇒ Bad vs. Better Policies
- Vehicle fleet dynamics, mode change, etc.
- Simulation over multiple years ($CO_2$ Emission, Energy demand, Investments, Tax redistribution, etc.)

# Questions?