Cost-benefit Analysis of Residential On-Site E-Carsharing

Car2Flex - Provision of System Flexibilities from E-Vehicles for various End User Applications

Carlo Corinaldesi, Georg Lettner, Daniel Schwabeneder (Vienna University of Technology)

Matthias Zawichowski (im-plan-tat Raumplanungs GmbH & Co KG)

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The flagship project Car2Flex (880780) has received funding from the 3rd call of the research and innovation programme Energy Model Region - Klima- und Energiefonds.

car2flex

Project Overview

Flagship project: Car2Flex

Project dates: 01/2021 – 12/2024

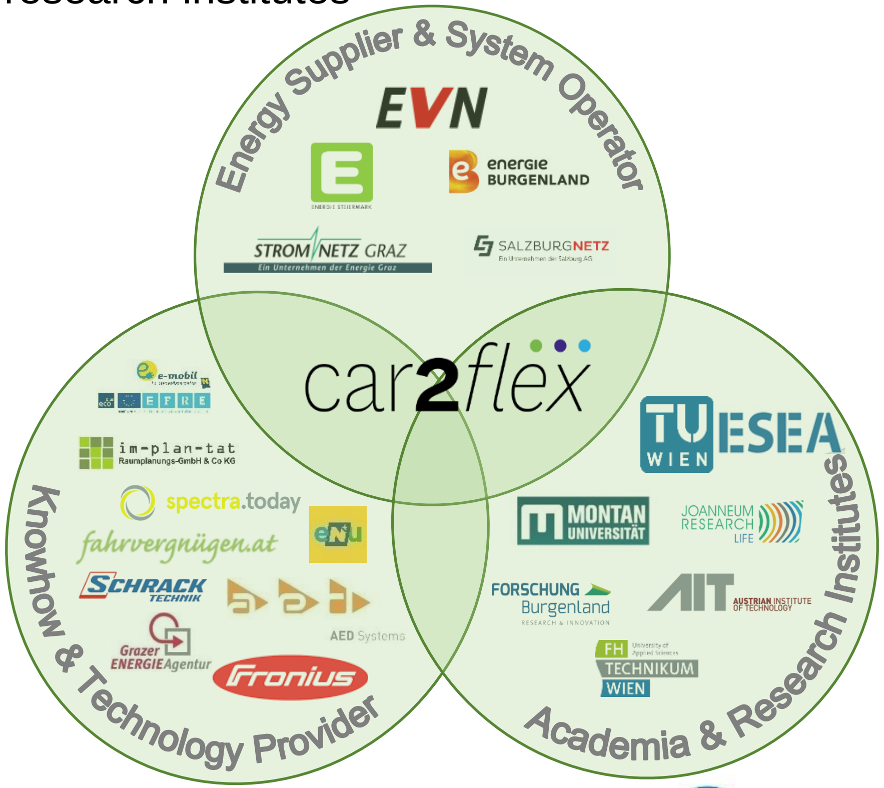
Project budget: 4,798,099.- EUR

Grant: 2,757,684.- EUR

Project management: TU Wien – Institute of Energy Systems and Electrical Drives

19 Project partners:

- 3 Technology providers
- 5 Energy suppliers and system operators
- 5 Users and multipliers
- 6 Academia & research institutes



Scale-up and Rollout	• Long-term demonstration phases • Large-scale grid analysis • Transferability
End-user Integration	• Questioning of end-users • Citizen science approach • Web/mobile application
Services & Business	• Adaption of e-Car Sharing Platforms • Novel operational management strategies • Cost optimization • Use of EV batteries as backup power • Extension of the local energy management
Technology Innovation	• Active Grid support EV charger • Standards • Simplification • Integration in building energy management

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Motivation

- *“Carsharing is a growing phenomenon in the world. Previous research concerning the subject has established that local governments often enable carsharing by providing privileged access to parking because of the expected benefits associated with it. (J. Raaska et al. 2020)“*

➢ Research question 1: What are the financial benefits of residential on-site E-Carsharing?

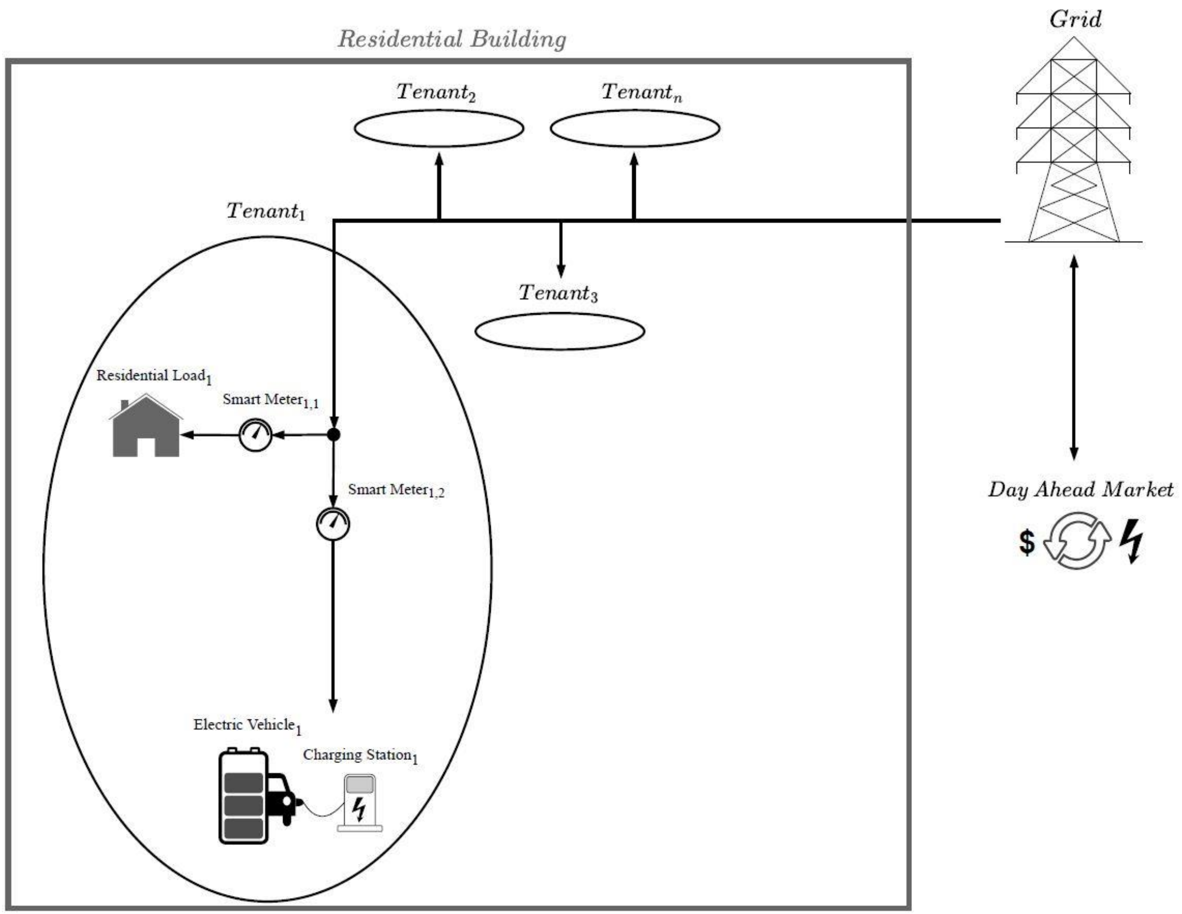
➢ Research question 2: How much can the space needed for parking be reduced?

➢ Research question 3: What is the impact of an E-Carsharing concept for a residential building?

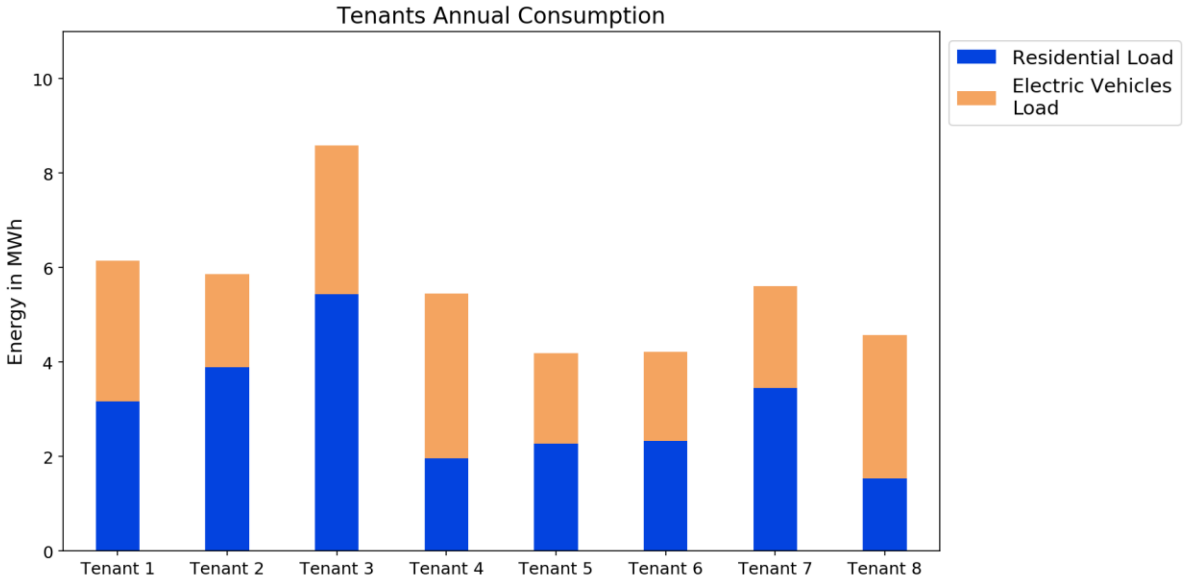
➢ Research question 4: In which set up does it become cost-effective to perform V2G?

➢ Research question 5: How can we construct a comprehensive mathematical E-Carsharing model to answer these questions?

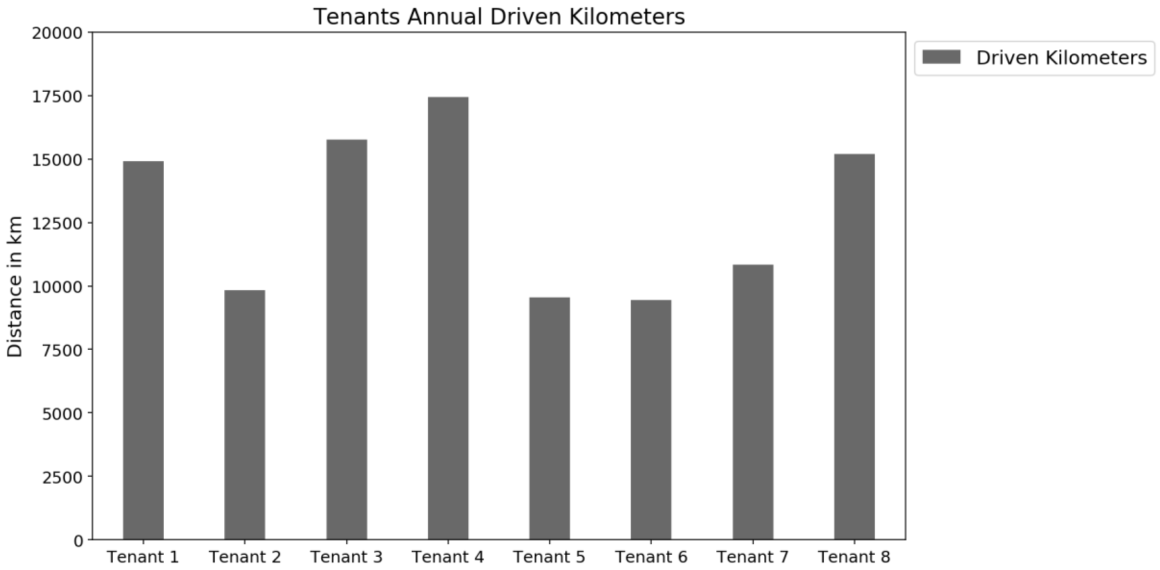
Case Study



Residential Building
Grid
$Tenant_2$
$Tenant_n$
$Tenant_1$
$Tenant_3$
$Residential\ Load_1$
$Smart\ Meter_{1,1}$
$Smart\ Meter_{1,2}$
$Electric\ Vehicle_1$
$Charging\ Station_1$
Day Ahead Market
$

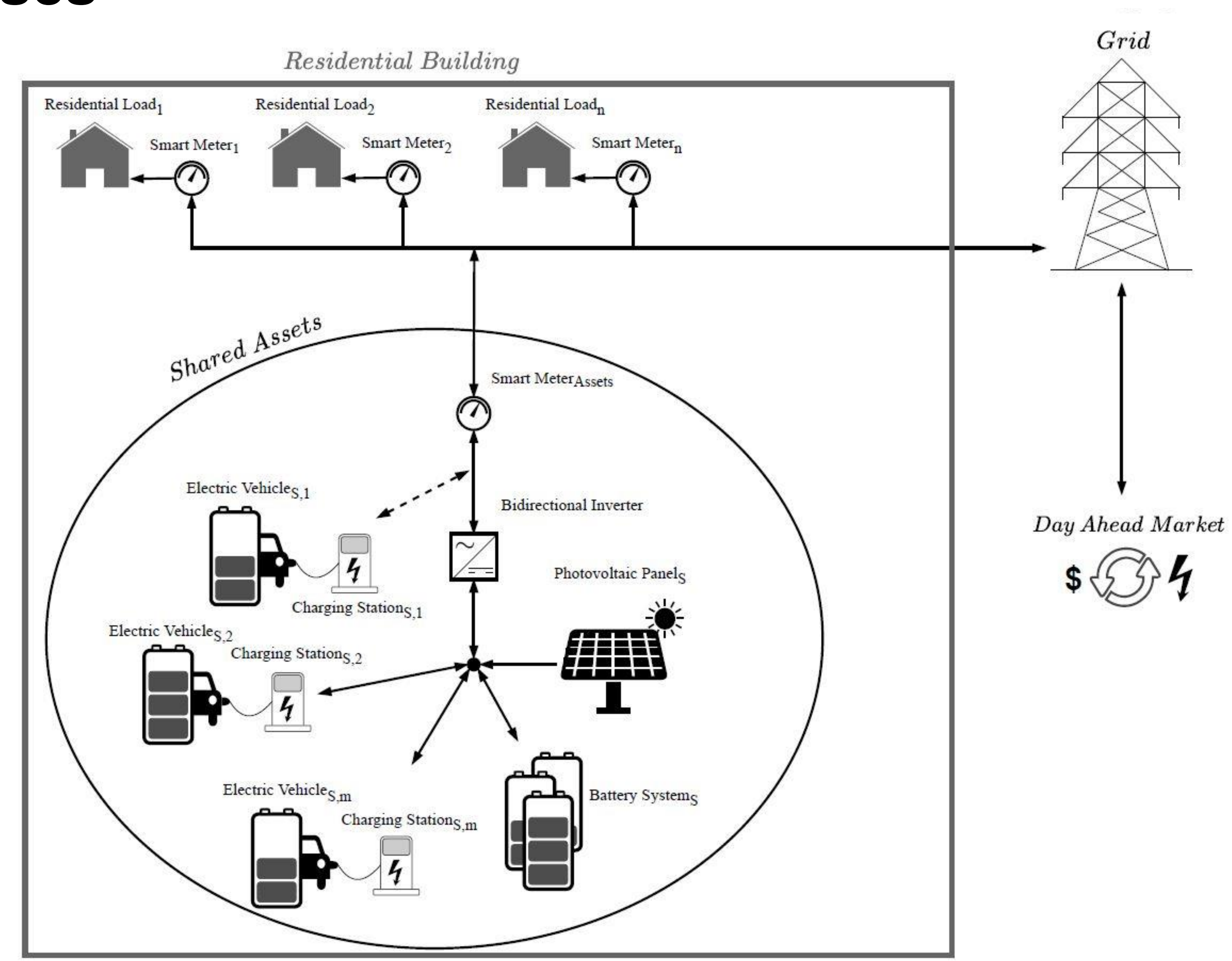


Tenants Annual Consumption
Residential Load
Electric Vehicles Load
Energy in MWh
0
2
4
6
8
10
Tenant 1
Tenant 2
Tenant 3
Tenant 4
Tenant 5
Tenant 6
Tenant 7
Tenant 8

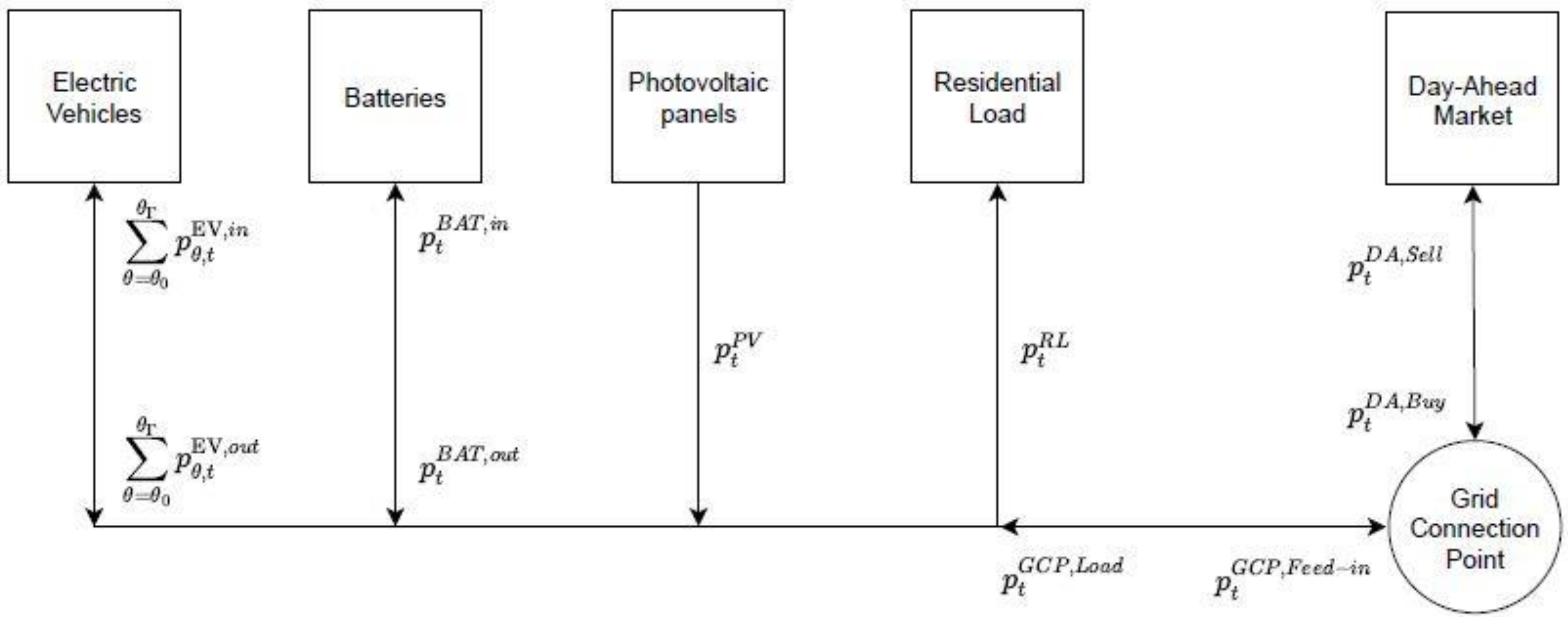


Tenants Annual Driven Kilometers
Driven Kilometers
Distance in km
0
2500
5000
7500
10000
12500
15000
17500
20000
Tenant 1
Tenant 2
Tenant 3
Tenant 4
Tenant 5
Tenant 6
Tenant 7
Tenant 8

Use Cases


Residential Building
Residential Load1
Residential Load2
Residential Loadn
Smart Meter1
Smart Meter2
Smart Metern
Grid
Shared Assets
Smart MeterAssets
Electric VehicleS,1
Bidirectional Inverter
Photovoltaic PanelS
Charging StationS,1
Electric VehicleS,2
Charging StationS,2
Electric VehicleS,m
Charging StationS,m
Battery SystemS
Day Ahead Market
$

Optimization Framework



<u>Power Balance at the Grid Connection Point:</u>

$$p_t^{\mathrm{GCP,Load}} - p_t^{\mathrm{GCP,Feed-in}} = p_t^{\mathrm{RL}} + \sum_{\theta=\theta_0}^{\theta_\Gamma} \left(p_{\theta,t}^{\mathrm{EV},in} - p_{\theta,t}^{\mathrm{EV},out} \right) + p_t^{\mathrm{BAT,in}} - p_t^{\mathrm{BAT,out}} - p_t^{\mathrm{PV}}$$

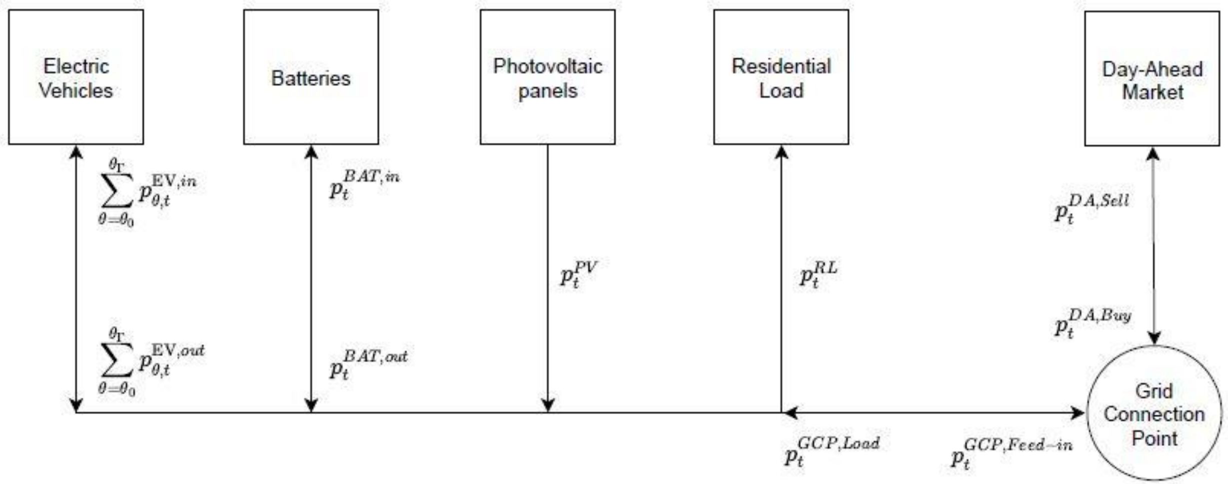
<u>Total Costs:</u>

$$C^{\mathrm{Total}} = C^{\mathrm{DA}} + C^{\mathrm{Grid}} + C^{\mathrm{BAT},LCOS} + C^{\mathrm{PV}} + C^{\mathrm{EV}}$$

Objective:

$$\min \quad C^{\mathrm{Total}}$$

Optimization Framework



Total Costs:

$$C^{\text{Total}} = C^{\text{DA}} + C^{\text{Grid}} + C^{\text{BAT},LCOS} + C^{\text{PV}} + C^{\text{EV}}$$

$$C^{\text{DA}} = \sum_{t=1}^{T} \left(\left(p_t^{\text{GCP,Load}} - p_t^{\text{GCP,Feed-in}} \right) \cdot P_t^{\text{DA}} \right)$$

The Day-Ahead costs are given by the product of the power flow at the grid connection point and the Day-Ahead Market prices

$$C^{\text{Grid}} = C^{\text{Grid,E}} + C^{\text{Grid,P}} + C^{\text{Grid,FR}}$$

The grid costs consist of three components and depend on the grid level: an energy-related component, a power-related and a fixed flat rate.

$$C^{\text{PV}} = p_{inst}^{\text{PV}} \cdot c^{\text{PV}}$$

The photovoltaic costs are given by the product of the installed capacity and the annual specific investment costs in EUR/kWp.

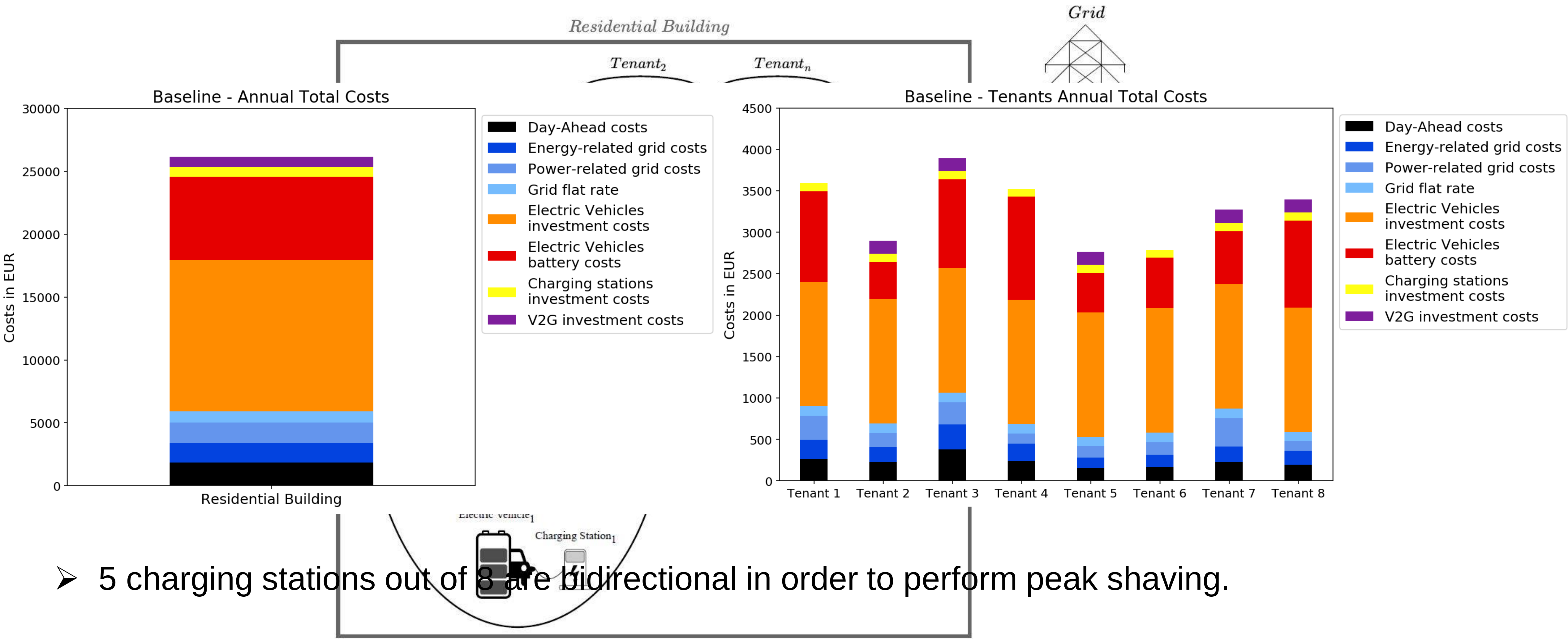
$$C^{\text{BAT},LCOS} = \sum_{t=1}^{T} p_t^{\text{BAT,in}} \cdot \Delta t \cdot c^{\text{BAT},LCOS}$$

The battery costs are given by the product of the overall battery usage and the levelized costs of storage (LCOS).

$$C^{\text{EV}} = C^{\text{EV},Inv} + C^{\text{EV},LCOS} + C^{\text{EV},CI} + C^{\text{EV},V2G}$$

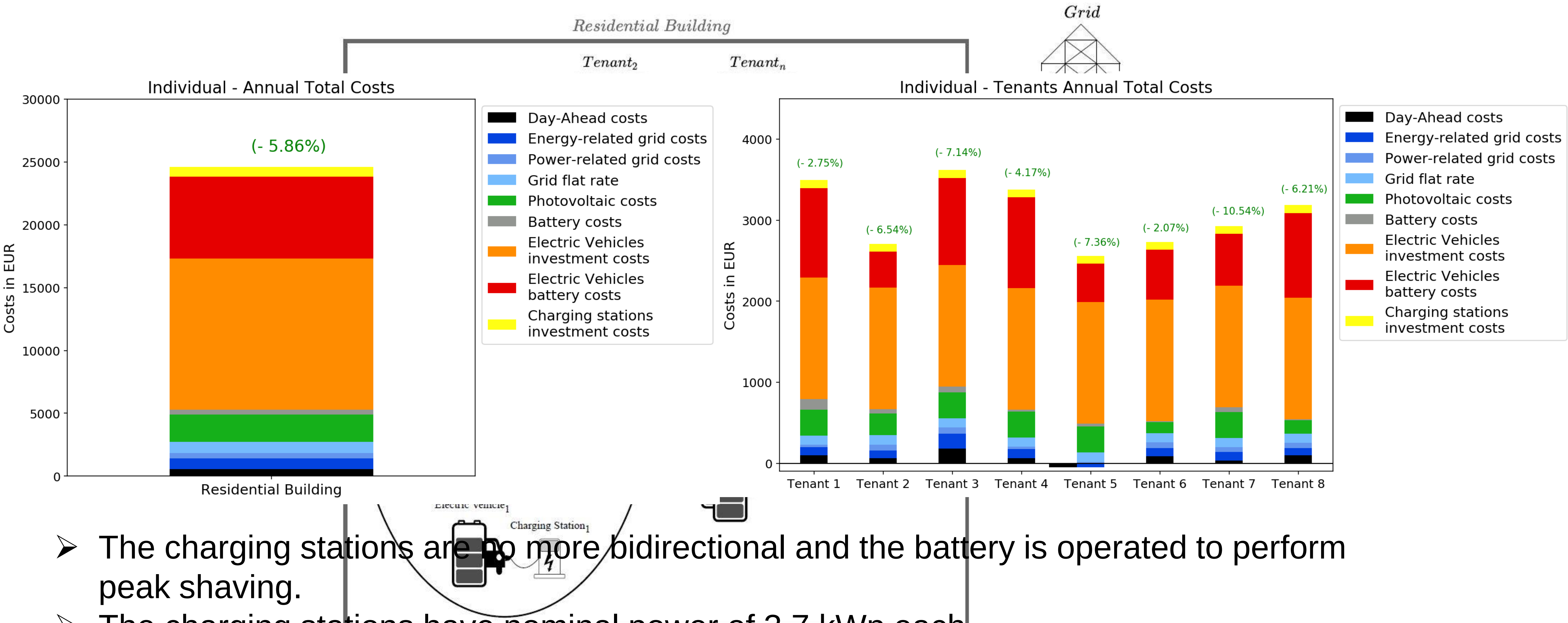
The electric vehicles costs consist of four components: Investment costs of the electric vehicles, the electric vehicles levelized costs of storage, the investment costs of the charging stations and the investment costs for the bidirectionality of the charging stations.

Results - Baseline



- 5 charging stations out of 8 are bidirectional in order to perform peak shaving.

Results - Individual



- ➢ The charging stations are no more bidirectional and the battery is operated to perform peak shaving.
- ➢ The charging stations have nominal power of 3.7 kWp each.

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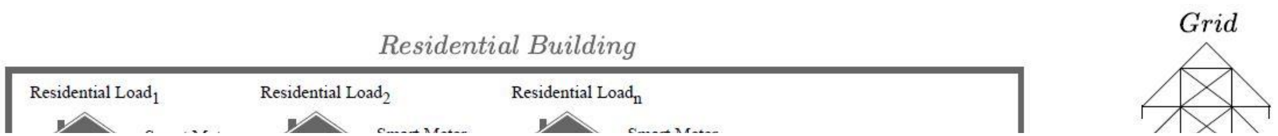
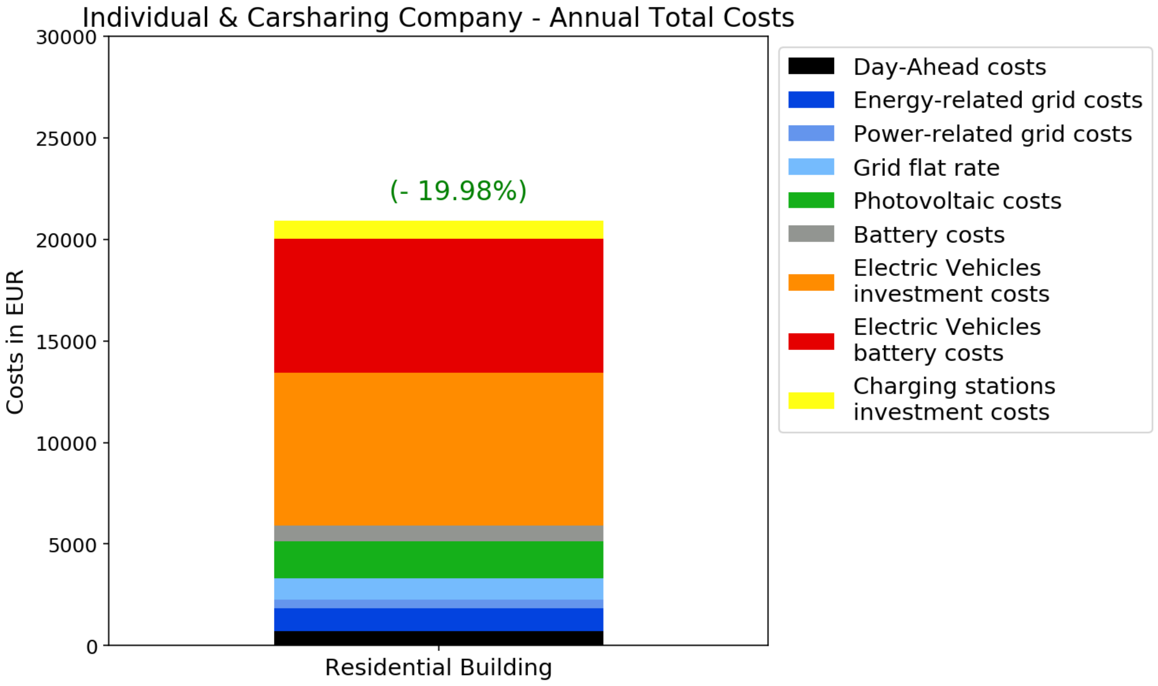
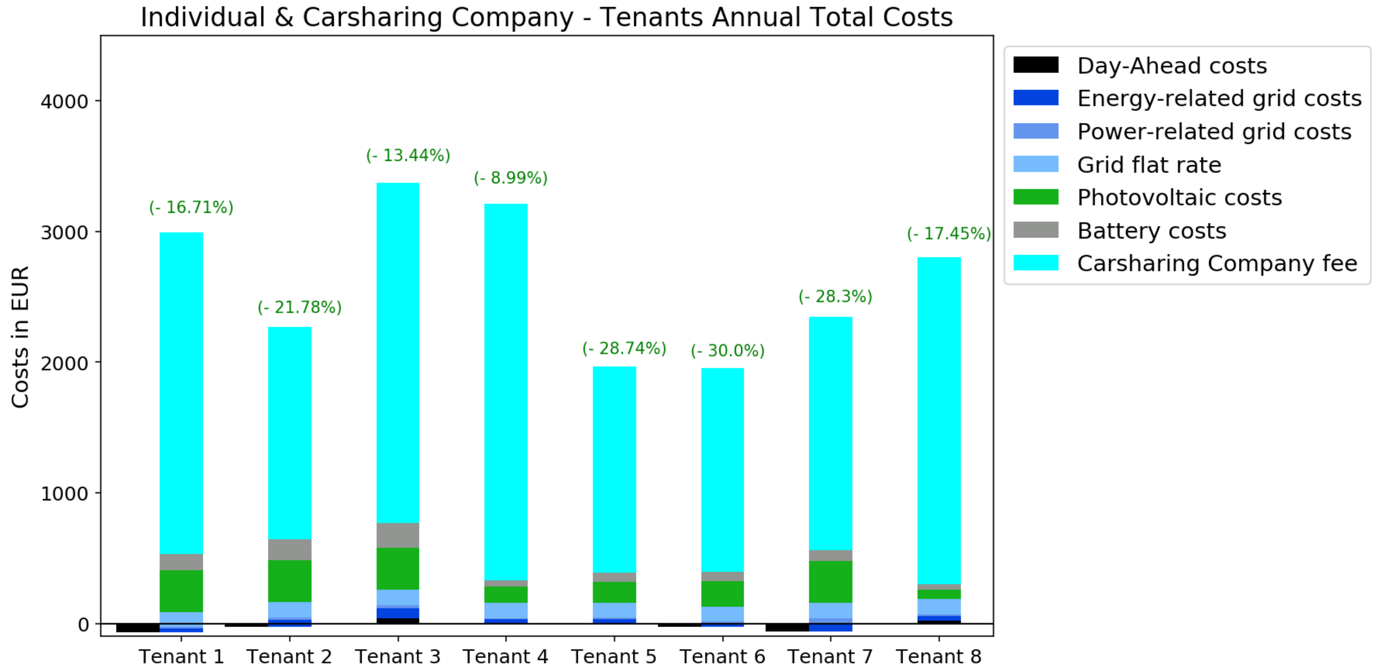
Results – Individual & Carsharing Company

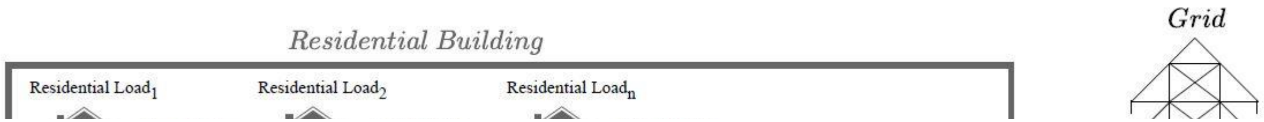


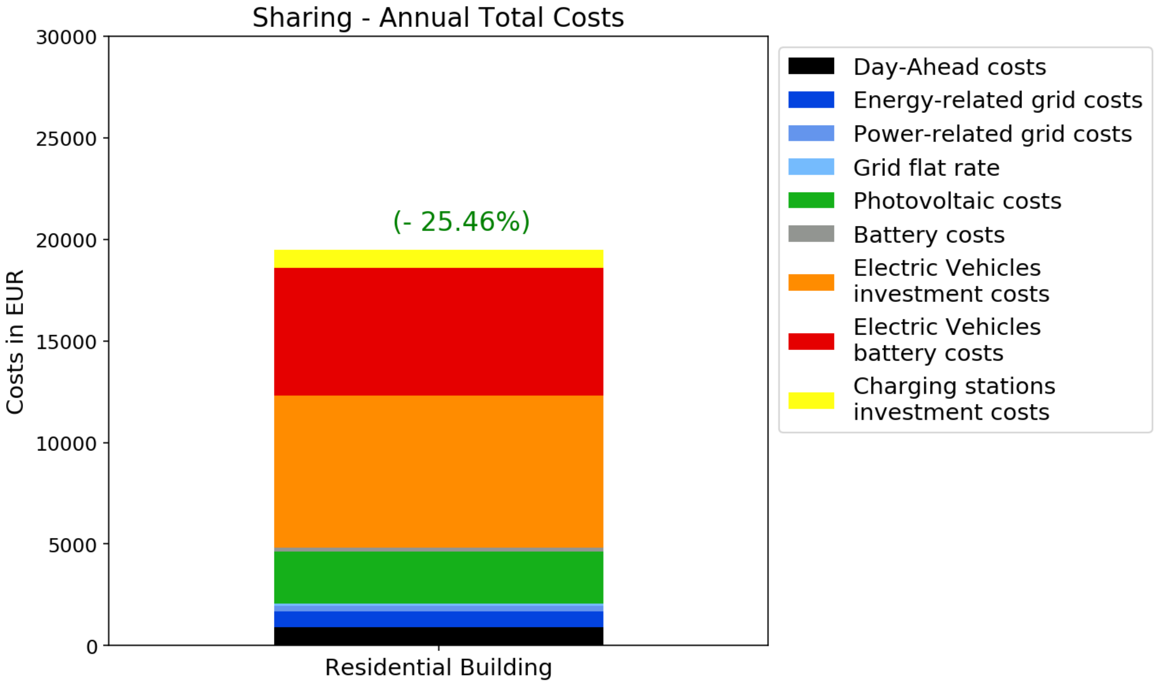


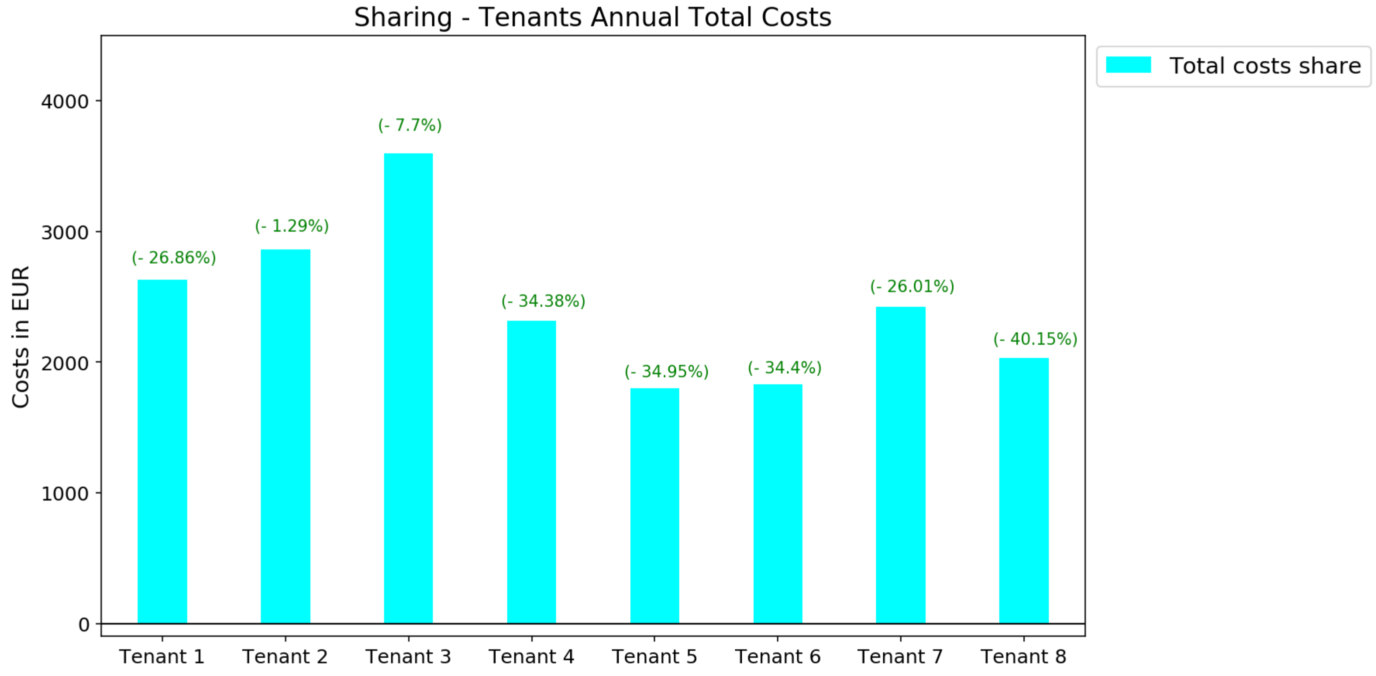


- **The application of the E-Carsharing concept allows to invest in 5 cars instead of 8!**
- 3 charging stations have nominal power of 11 kWp and the remaining 2, 7.4 kWp.

Results – Sharing

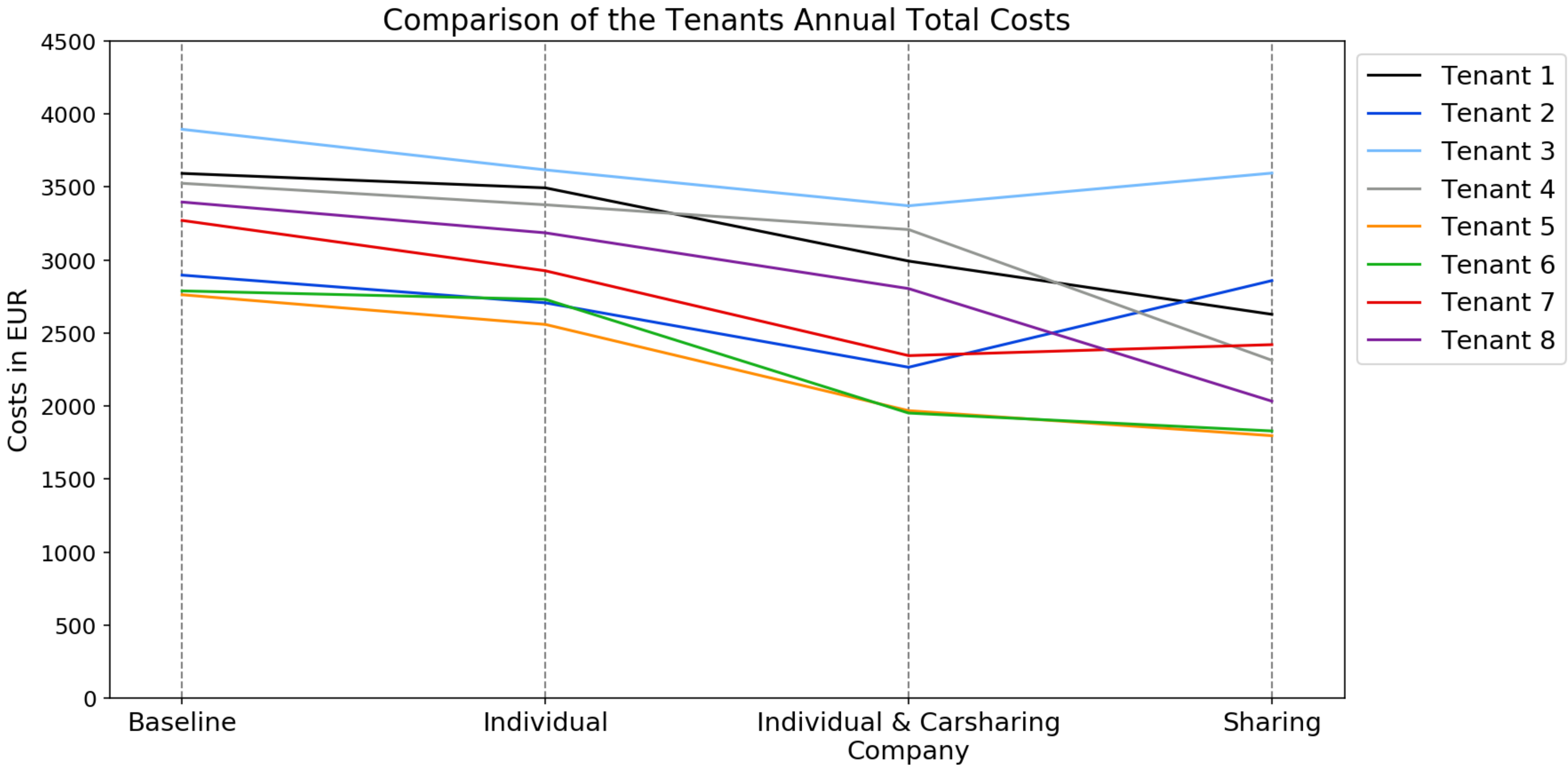






- ➢ The application of the E-Carsharing concept lead to considerable costs reductions.
- ➢ However, the costs savings are not shared equally between the Tenants.

Comparison of the Tenants Annual Total Costs in the different Use Cases



Conclusions and Outlook

- Our work presents a comprehensive overview of modeling and evaluating the potential of a residential E-Carsharing concept and shows how residential on-site E-Carsharing can lead to considerable overall costs reductions.

- It is noted that if it is not possible to invest in a stationary battery, it becomes cost-effective to perform V2G for peak-shaving.

- The E-Carsharing concept allows for fewer cars, but charging stations with higher nominal power are required.

- The model will be tested and validated in different real-life use cases in Austria within the flagship project Car2Flex.

- It will be investigated whether other markets, such as the reserve markets, can make E-Carsharing and V2G even more cost-effective.

Thank you for your attention

Carlo Corinaldesi

[T] +43-(0)1-58801-370370
[E] corinaldesi@eeg.tuwien.ac.at

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