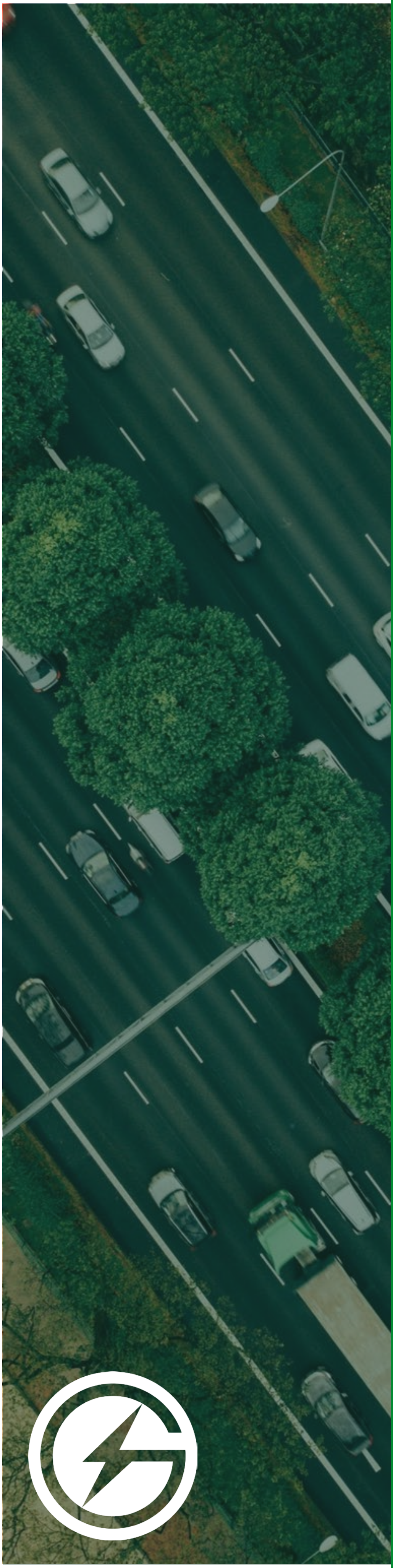

GRID AWARE MOBILITY AND ENERGY SHARING

INDUSTRY WHITEPAPER

NEW BUSINESS OPPORTUNITIES LEVERAGING THE FLEXIBILITY POTENTIAL OF ELECTRIC SHARED VEHICLE FLEETS

EXECUTIVE SUMMARY

by

Guntram Pressmair, e7

Jakob Papouschek, e7

Michael Thelen, SRFG

Roberto Rocchetta, SUPSI

Jalomi Maayan Tardif, SUPSI

Aviva Shemesh, RUNI

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1 INTRODUCTION

The concept of using electric vehicles (EVs) as flexible storage seems simple and convincing: There are countless cars spread out throughout our cities, but most of the time they stand idle. With modern cars having battery capacities between 50 and 100 kWh, this sums up to vast amounts of battery storage being available for supporting electricity grids and shifting energy demand towards times of renewable surplus generation. But what sounds like a low hanging fruit in theory faces a lot of practical barriers: How to coordinate all those cars efficiently? Does it affect the lifespan of the batteries? And most important, is there actually a viable business model for both fleet owners and energy industry? Focussing on latter question, this whitepaper analyses different business opportunities in four case studies:

Table 1: Case study description

1	**PV self-consumption optimisation** at a corporate headquarter in Austria, targeting the company's electric vehicle fleet.
2	**Peak shaving** for better grid stability in the city of Zurich with the help of a large-scale station-based car-sharing fleet.
3	**Profit-optimized energy trading** using batteries of a stationary car-sharing fleet in Zurich as storage for dynamic energy prices.
4	**Large scale PV surplus utilization** within a high-solar energy system of the Tel Aviv metropolitan area in the year 2030, including a large free-floating car-charging fleet.

These business opportunities are explored through the deployment of intelligent charging strategies for electric vehicles, operated as shared vehicle fleets. Intelligent charging (strategies) in this document refers to the use of price-controlled charging (smart charging) and the application of vehicle-to-grid technology (V2G).

Smart charging enables adjusting the power level and timeframe of the charging process. The charging parameters are dependent on external (price) signals. E.g., an EV can be slowly charged overnight, when electricity prices are low.

Bidirectional charging (vehicle-to-grid – V2G) is an enhancement of smart charging. Bidirectional charging allows energy to flow back. E.g., not only from the grid to the battery, but also from the battery back to a building or the grid.

Based on the introduced case studies, the authors analyse energy prices, tariff structures, fleet sizes and much more needed to make such business models a reality. The analysis is based on real and simulated mobility data retrieved from the national partners in Switzerland (mobility.ch and SUPSI university) and Israel (AutoTel and Reichman University). Core element of the evaluation is the "e7 flexibility model", specifically developed for the GAMES project by the Austrian research and consulting company e7 energy innovation & engineering.

2 FLEXIBILITY MODEL

In the course of the GAMES project, 4 different case studies are presented which analyse the economic (business opportunities) and ecological potential of electric vehicle car-sharing fleets. The potential analysis is accomplished with the utilisation of mathematical optimisation, employing the optimisation software "GAMS" (Generic Algebraic Modeling System). The optimisation model is formulated as a linear optimisation problem and is applied in different variations for the case studies. In every version, it contains the following core elements (equations): objective function, energy balance equation and the EV battery equation. In addition to the core equations, the model versions contain various constrains or other additional elements to address the respective research questions.

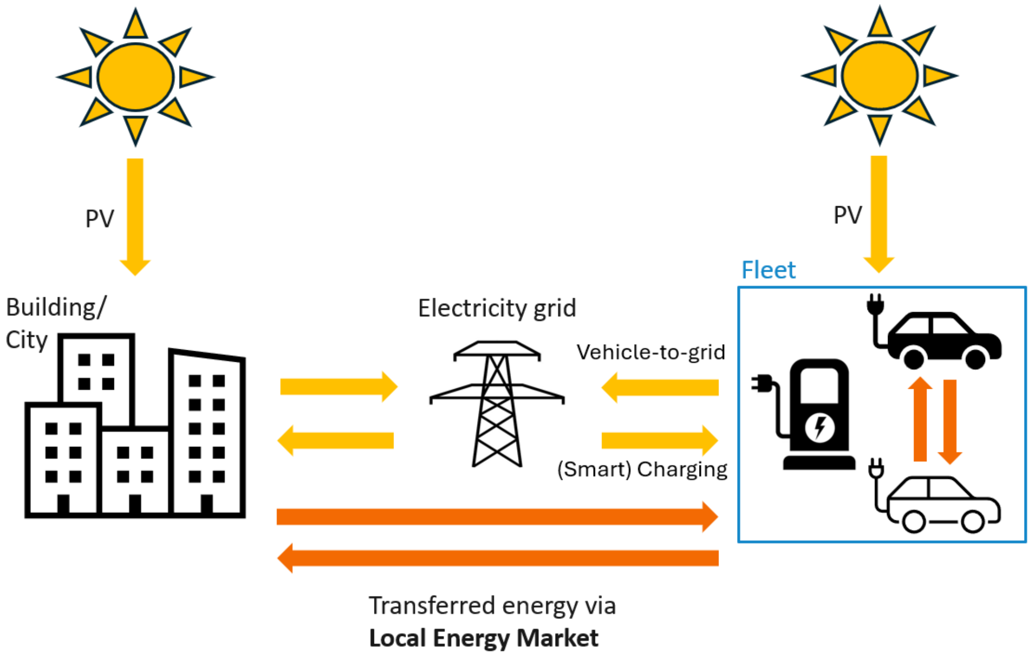

Figure 1: Overall model outline

Figure 1 shows a schematic illustration of the core elements of the optimisation model. Individual actors (city and fleet) can directly purchase energy from the electricity grid or sell energy to the grid. In addition, energy can be exchanged directly using the local energy market (LEM). Individual vehicles within the fleet are able to utilise the LEM to exchange energy with one another. Furthermore, PV-production can be incorporated into the model. Figure 1 represents the maximum possible applications of the model. The individual case studies do not contain all but only parts of the energy system illustrated. Depending on the case study and the scenario investigated, certain sub-elements of the optimisation model are applied, and the results analysed.

3 CASE STUDY 1: WINDKRAFT SIMONSFELD

Description

Windkraft Simonsfeld AG is a wind farm operator located in the Austrian village Ernstbrunn. The headquarter is equipped with a large sized 70 KW$_p$ rooftop PV and an electric company fleet, consisting of 26 EVs. The cars are mainly used for business trips and are parked and charged in front of the headquarter. EVs can charge energy from the grid or the PV and are able to sell energy back to the grid or shift energy to another vehicle. The research focus of this case study is on the business case for smart and bidirectional charging (V2G) for a real corporate fleet. In other words, cost saving potential through **PV self-consumption optimisation** on site and realistic **dynamic energy pricing** schemes available on the market. Several scenarios have been modelled and compared, the variables changed are energy price structure (static or dynamic prices), availability of PV and application of technology (smart charging or V2G). The timeframe of the case study is 6-12 months.

Main results

Smart charging: in a set-up without PV and with dynamic electricity prices, smart charging can reduce energy costs by **27%** compared to uncontrolled charging. Within a set-up including PV and static energy prices, smart charging manages to reduce energy costs by **68%** by charging in periods of PV surplus generation.

V2G: in a set-up without PV and with dynamic prices, V2G can reduce energy costs by **29%**, in comparison to uncontrolled charging. In addition, the fleet is able to sell energy to the grid and therefore the total balance (revenue from energy sales minus energy costs) of the fleet is increased by **46%**. In the same set-up, including PV, the total balance is increased by **46%** as well. Within a set-up including PV and static prices, V2G decrease energy costs by up to **93%** and the total balance is increased by **14%**. If battery degradation costs are included into the optimization, potential profits from energy sales are approximately halved. In certain set-ups including high battery degradation costs, degradation costs can even negate the entire profit.

The absolute monetary added values of smart charging and V2G are very low and range between **0,9 – 4,1 Euro** per month per vehicle. This can be explained by low energy costs of the fleet, caused by the large amount of generated PV energy.

Conclusions

- Smart charging is a low hanging fruit to reduce energy costs
- V2G has the potential to generate profits through energy trading
- Battery degradation costs are relevant
- Monetary values of smart charging and V2G are modest, however both enable notable benefits in relative terms

4 CASE STUDY 2: ZURICH 1 – PEAK SHAVING

Description

This case study is located in the city of Zurich and examines the potential of a large station-based car-sharing EV fleet to stabilise the electricity grid. More specifically, the study analyses how a big EV fleet (24 000 EVs) can provide flexibility services to the grid. This means a reduction of the peak load (peak shaving) in Zurich, which is made possible by EVs feeding in energy or postponing charging. A real load profile for Zurich is used for this purpose. The mobility data of the EV fleet is provided by the Swiss car-sharing provider "mobility.ch". Time horizon is approximately 39 hours. Static and dynamic electricity prices as well as a peak power tariff are based on realistic prices in Zurich. In 10 scenarios, the effects of various price structures and the use of smart charging and V2G are examined.

Main results

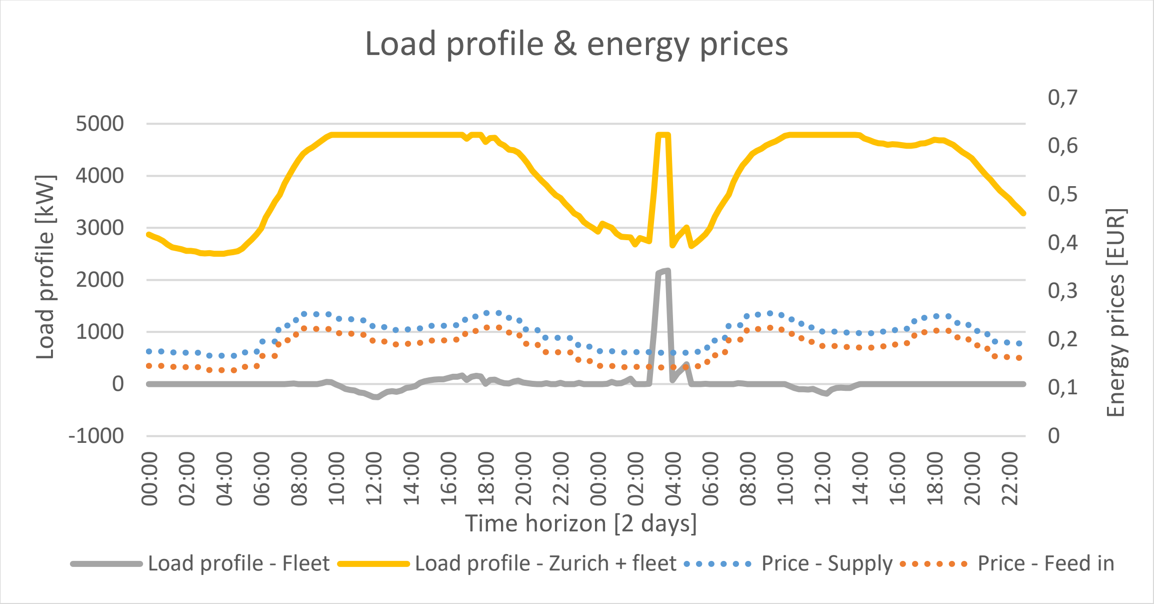

Figure 2: Chart of Zurich's load profile, energy balance and price structure

Figure 2 illustrates the impact of an exceptionally high peak power tariff in combination with an intelligently charging (smart charging and V2G) EV fleet on Zurich's load profile. Energy is sold by the EV fleet to reduce the load peaks. Furthermore, energy is charged at times of low prices. As a result, a smoothed load profile with a reduced load peak **(-6%)** is noticeable.

Conclusions

- Future EV fleets have the battery capacities for grid stabilisation
- Realistic electricity price structures hardly incentivise peak shaving
- Economic incentives for peak shaving require an exceptionally high peak power tariff and available battery capacities

5 CASE STUDY 3: ZURICH 2 – ECONOMIC DISPATCH

Description

The second case study located in the city of Zurich focusses on economic aspects of an EV fleet from the fleet operator’s perspective. The EV fleet is a station-based EV fleet and consists of 495 vehicles. 274 EVs are active, 221 are inactive and are only used for energy trading. The mobility data of the EV fleet is provided by the Swiss car-sharing provider “mobility.ch”. Time horizon of the optimisation is 48 hours. Different realistic electricity price structures are applied. 6 scenarios have been modelled and compared, the variables changed are energy price structure (static or dynamic prices), and application of technology (smart charging or V2G).

Main results

Smart charging: in a set-up including an average dynamic tariff, energy costs are reduced by **5,9%**. The reduction is modest due to the small price range of the dynamic tariff (electricity price between 0,22 and 0,25 Euro/kWh). Smart charging in combination with a highly fluctuating tariff (price between -0,01 and 0,24 Euro/kWh), can reduce energy costs by **49%.** However, in the study set-up, such price fluctuations are very rare and only occur a few times a year.

V2G: the combination of V2G and a highly fluctuating dynamic tariff shows the full potential of the technology. Energy costs can be reduced by **59%**. In addition, V2G generates significant profits, which are 140% larger than the originally energy costs without V2G. Consequently, energy costs are reduced, and profits are generated. However, sufficiently fluctuating dynamic prices are rare. When battery degradation costs are added in the optimisation model, the balance deteriorates and almost negates the entire trading profit. Nevertheless, the total costs fall by **94%.** Within this specific set-up (characterised by low energy costs), V2G in combination with a fluctuating dynamic tariff can generate monetary value of up to **14,4 Euro** per vehicle per month.

Conclusions

- V2G and dynamic prices have the potential to significantly reduce energy and total costs
- An EV fleet used for energy trading generates minimal profits
- The applied realistic price structures offer hardly any opportunities for energy trading
- Profits form electricity trading require a sufficiently wide price range
- Battery degradation costs are relevant and have the potential to prevent a profitable application of V2G

6 CASESTUDY 4: TEL AVIV

Description

This case study analyses the possible utilization of surplus energy generated during peak PV periods with the help of a free-floating car-sharing EV fleet. The study is located in Tel Aviv and is situated within the context of the year 2030. 18 scenarios explore how much surplus PV-energy can be stored by future EV fleets (up to 42 000 EVs) for later use. Furthermore, economic and ecological aspects (CO_2 reduction) are also analysed in more detail. The variables changed are fleet size, PV size, mobility behaviour and application of technology (smart charging or V2G). Fleet size varies between 10 500 and 42 000 EVs. The assumed PV-production ranges between 33 and 50% of the city's total energy consumption, which is a very ambitious assumption. Input data regarding the mobility behaviour of the car-sharing fleet is based on real mobility data provided by the car-sharing provider "Autotel" (Isreal).

Main results

City perspective: smart charging and V2G technology increase the PV surplus utilization rate in every scenario, with V2G always achieving the highest PV surplus utilization rate. In relative terms, the highest PV utilization rate reaches **22,39%**. This is achieved in a scenario including a big fleet and the lowest assumed PV-production. The highest absolute amount of utilised surplus energy is realised in a scenario including a big fleet and a big PV, which is approximately **5%** of the total PV-energy surplus. However, the maximum amount of PV surplus energy utilized accounts for only **0,41%** of total city energy consumption.

Fleet perspective: in this specific set-up, an EV fleet can save up to **56%** of its energy costs through the use of smart charging and up to **58%** utilizing V2G. In addition, with the help of V2G, more surplus PV energy can be utilised than the fleet originally consumes. As a result, energy originally purchased from the grid (assumed fossil) can be significantly reduced and replaced by low emission PV surplus energy. Therefore, the application of V2G has a CO_2-reducing effect. Furthermore, if energy prices are low, the monetary value of CO_2 reduction can be financially significant.

Conclusions

- A limited proportion of surplus PV energy can be utilised by an EV fleet. However, the amount of utilised energy is not system relevant

- Mobility behaviour affects the fleet's potential for surplus PV utilisation

- Smart charging can significantly reduce the energy costs of an EV fleet. V2G can even generate profits

- V2G can enable a nearly climate-neutral vehicle

- Large scale surplus PV utilization requires a tremendous EV fleet

7 CONCLUSION – DERIVING FUTURE BUSINESS MODELS

Based on the analysis of the case studies presented above, the following key conclusions are drawn for future flexibility business models:

Table 2: Key conclusions per flexibility use case

Use case	Conclusion	Pros (+) / Cons (-)
PV self-consumption	Currently the **simplest** and **most profitable** flexibility use case for EVs. Smart charging can save energy costs, V2G can generate profits.	+ also saving (energy-based) grid fees + no external barriers to this use case + feed-in prices will decrease - only for sites with PV
DSO peak shaving	Not expected to be market-ready in the medium term, **significant regulatory changes needed** to make it profitable.	- limited impact by EVs on big urban grid - peak load costs of DSO too low - market platform or dynamic grid tariff needed
Profit-optimized energy trading	Currently **not a standalone business case** but can create meaningful cost savings on **specific days** with high price volatility.	+ will be more profitable with increasing volatility - savings only on energy price - double grid charges may apply - price spread mostly too low for V2G
Large scale PV surplus utilization	Under current conditions not feasible. Ramp-up of electromobility is not yet sufficiently advanced.	- requires a multiple of today's EVs and PV production - minimal financial incentive for players in the energy system

To summarise, a mixed picture emerges. In theory, future car-sharing EV fleets will have considerable aggregated battery capacities to store energy for later use. EVs can therefore be seen as a valuable flexibility resource. On closer examination, however, several limitations to future flexibility business models were identified within the GAMES project. On the one hand, the necessary mass of EVs is still not available for business models that provide significant added value for the entire energy system. On the other hand, necessary framework conditions are only partially in place. System-relevant flexibility business models require a sufficiently large PV-production or well-designed electricity pricing schemes, such as dynamic tariffs. In order to achieve any benefit or added value with the help of an EV fleet, it is crucial that a sufficiently large fleet is available in the first place and that the single EVs also have correspondingly long idle times. Nevertheless, the notable potential of EV fleets has been demonstrated, especially in conjunction with PV-production and V2G technology. Combined with PV and V2G, EVs can save considerable amounts of energy, resulting in significant economic and environmental benefits.

8 DISCLAIMER

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