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Prediction on future electric vehicle market shares in urban areas and related consequences for energy delivery & grid stability – investigation of Stuttgart

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Executive Summary

The goal of this study is to analyze the effects of the upcoming market penetration of battery electric vehicles (BEV) and plug-in hybrid vehicles (PHEV) on the grids of the Stuttgart Region. At first, forecasts of the xEV (BEV +PHEV) share of the vehicle fleet in 2030 are issued. Therewith, the electric energy consumption of the xEV is calculated together with the total power demand. In addition, the travel behavior of the people in the Stuttgart Region is simulated. This is essential to gain knowledge regarding the spatial and temporal distribution of the energy demand. Thereby the charging characteristics of an example area in the City of Stuttgart are determined and a load flow analysis is made on the corresponding electricity grid topology to identify the impact on the transformer and the cable. As a result we conclude that the impact on the electricity grid is marginal in 2030.

Keywords: battery electric vehicle, city traffic, charging, energy consumption, demand, energy, infrastructure

1 Market analyses and electric mobility forecasts

Throughout Europe, more far-reaching climate protection targets are being pursued and implemented that influence both the primary energy supply market and transportation. When it comes to transportation, the standardized taxation of fleets throughout Europe is an essential instrument for paving the way to more efficient powertrain technologies [1]. Automotive manufacturers are currently preparing for a product offensive of battery-powered vehicles that will act as a key element in achieving designated CO_2 fleet emission targets by 2030. The success of this technology largely depends on customer acceptance and the availability of a sufficiently dimensioned charging infrastructure, whereby there will most likely be pronounced differences throughout Europe. The following study is focusing on the Stuttgart Region. First, we estimate the potential market diffusion of electric vehicles (xEV) in the region (cf. Chapter 1) before we derive the corresponding energy demand for the Stuttgart Region (Chapter 2). Then, we present a microscopic simulation of the region (Chapter 3) and conduct a load flow analysis in order to identify the resulting grid impact on the electricity grid (cf. Chapter 4).

1.1 Vehicle base and market distribution by type of registration

The passenger cars are the most important sector based on their sheer numbers. In total, the 46.5 million passenger cars in the vehicle fleet in Germany had a total mileage of 630 million kilometers in the year 2017, or 86% of the total annual mileage driven on the roads of Germany [2]. In October 2018, the European Union confirmed the reduction of average CO_2 fleet emission targets for passenger cars and light commercial vehicles by 2030 within the framework of an agreement between the European Council and the European Parliament. This requirement is aimed at automotive manufacturers as the targets are linked to a tax levy based on annual new registrations. The EU regulations on the passenger cars equipped with internal combustion engine (ICE) set a fuel consumption limit value of 95 gCO_2/km for the year 2020 and a further reduction to 81 gCO_2/km in 2025 and 59 gCO_2/km in 2030 [3]. These are limits which cannot be achieved with the conventional propulsion systems based on petrol and diesel alone, and define the need on alternative drivetrain concepts, such as xEV

In Table 1 the fleet of registered passenger cars and the xEV share of the stock are on display for Germany, Baden-Württemberg and the Stuttgart Region. The figures are from the year 2017 and show a marginal share of xEV. However, the xEV share of Stuttgart Region is more than twice as much as in Germany as a whole.

Table 1: Passenger car registrations in Germany [4]

Vehicle registrations	Germany	Baden-Württemberg	Stuttgart Region
ICE [number]	46,410,016	6,502,582	1,617,090
PHEV [number]	44,419	8,493	4,558
BEV [number]	53,861	10,568	4,617
xEV share	0.21%	0.29%	0.56%

The higher share in the Stuttgart Region suggests, that a disproportionately high penetration of xEV can be expected at key industrial locations in the future, especially in Germany. It is important to note, that higher xEV shares in such Regions are necessary to comply the targets of the EU. Because it can be anticipated that there will be countries in the EU which will be unable to hold the CO_2 fleet emission targets of the EU. So it is very important that Germany as the biggest market for passenger cars (approx. 3.4 million sales in 2018 [5]) in Europe takes a leading role in the electrification of the road traffic.

1.2 xEV vehicle registration forecasts by 2030

Based on the aforementioned EU CO_2 fleet emission targets forecast calculations for the xEV share in 2030 where made. On basis of these calculations a xEV share of approx. 23% was determined. As mentioned before Germany, and especially a region like Stuttgart, must outreach the EU CO_2 fleet emission targets. With regard to forecasts for the number of xEV registered by 2030, a (residual) inaccuracy remains after the real-world customer willingness and acceptance to switch to xEV vehicle concepts is disregarded. Therefore, additional market studies were examined. Current forecast calculations from the Boston Consulting Group, the Royal Dutch Shell Group and a study conducted by Öko-Institut e.V. were taken into account. The results of these studies differ considerably from each other because of the premises assumed (e.g. achievement of climate targets, fulfilment of fleet consumption targets, change in energy prices, etc.) and growth forecasts in relation to various influencing factors (market acceptance, price development, availability of infrastructure, etc.). It must be pointed out, that the original results of these studies are all based on calculations for Germany as a whole. Thus, the results of these studies where extrapolated to fit the special frame conditions of the Stuttgart Region. The studies are displayed in Figure 1 and the extrapolated results are marked with an (e). Only one extrapolated study clearly outreaches the calculated value based on the EU CO_2 fleet emission targets. It's the study of the Boston Consulting Group and it reaches a xEV share of 27%.

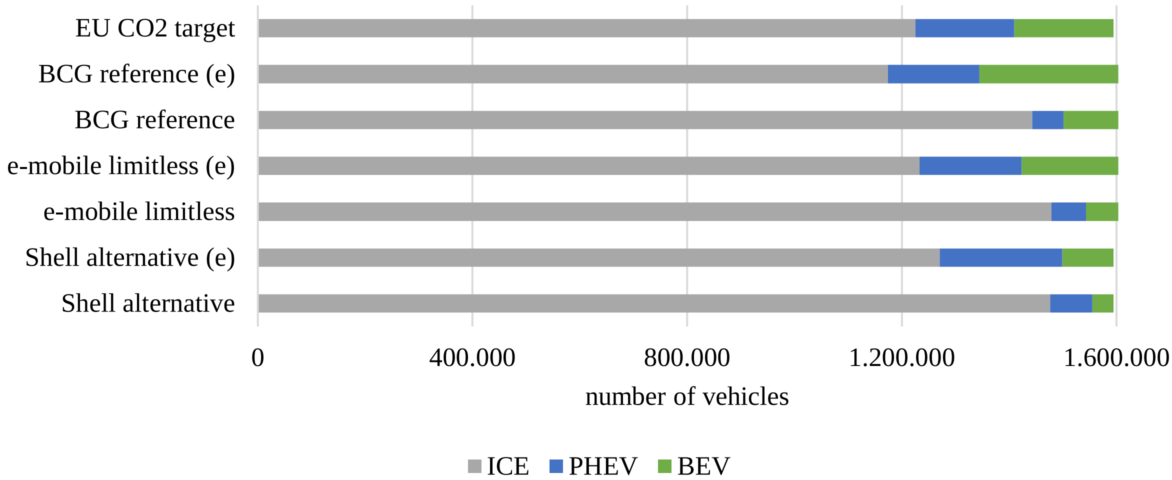

Figure 1: Forecasts of vehicle inventories for Stuttgart Region, differentiated by ICE, PHEV, BEV [6], [7], [8], [1].

To reach such high xEV shares in the future, the vehicle manufacturers and the legislator must generate customer acceptance for the new technology. In the short term in which the legislative pressure on the manufacturers is applied, supportive legislation could increase the customer acceptance and therefore help to achieve the ambitious xEV sales. Especially in regard of the public charging infrastructure legislative support in the early years is important, to kickstart the market and make it accessible for everyone.

On the long run the technology has to be sustainable on its own. This is possible due to falling battery system prices and therefore the TCO of the xEV can outreach the conventional engine systems from the end customer's point of view. Leading up to the 2019 International Motor Show in Frankfurt, new BEV are already being officially announced and should lead to an increase in sales in the market. All of these BEV are characterized by their ability to travel much greater distances, which ranges from 330 km to over 500 km, thanks to adapted battery capacities of 50 kWh to approx. 95 kWh.

2 Energy balancing of system participants ─ Case study Stuttgart

As part of this study, a model-based energy system analysis was conducted for the City of Stuttgart. The energy system model characterizes all processes of energy conversion and use in the city. The development of this energy system under energy policy frameworks is then observed over time.

The energy system analysis not only factors in these frameworks, but also the registration figures for xEV registration forecasts by 2030 (Figure 1). In addition to vehicle energy consumption, the increased penetration rate of electric mobility has systematic repercussions on other traffic, power generation and consumption as well as the achievement of local greenhouse gas emission reduction targets.

The underlying foundation is the TIMES Local energy system model. In TIMES, the energy system is represented bottom up and technology based in detail as a network of processes (e.g. power plant types, transportation technologies), goods (energy sources, materials) and the resulting emissions in the form of a reference energy system [9–11]. In the linear optimization model, the system base, future demand in the individual sectors and primary energy source prices as well as the parameters characterizing the technologies and energy sources are specified. TIMES Local is an application that focuses on considering those processes relevant for a city or neighborhood model. The target function is the integral minimization of costs in compliance with defined technical and ecological restrictions [12].

As part of the optimization, integral expansion and deployment optimization are carried out over the entire modeling period. To this end, the reference energy system factors in the sectors of public electricity and heat supply, private households, trade, commerce, services, transportation, industry and the importing of energy sources. To meet the requirements of flexible power feeds from renewable energies and dynamic consumers such as xEV, the time resolution is divided into five type weeks with hourly time increments. Four type weeks each correspond to a season (672 time increments per year), and the fifth characterizes a peak week with an hourly resolution (an additional 168 time increments per year) to illustrate a high feed-in of fluctuating renewable energies.

2.1 Scenario definition ─ Electromobility in Stuttgart

The analysis is rooted in a scenario based on the master plan for the City of Stuttgart [13]. According to the master plan, the objective of reducing greenhouse gas emissions by 95% as compared to 1990 by 2050 applies to the area in question. We implement the specifications of the master plan in two scenarios to different extents. In the "KLIM" scenario, we only adopt the requirements of the master plan in an attenuated form - this means population development, employment development and greenhouse gas reduction (-95% in 2050). In contrast, the "KLIMPLUS" scenario is more consistent with the planning specifications of the City of Stuttgart. In this scenario, a more progressive development of energy savings in industry is assumed as well as a modal shift towards public transport as a significant change for transport. In line with the plan for the City of Stuttgart, there will be a decreasing demand for mobility in motorized private transport which, in the model, will lead to a shift toward local public and railway transportation. We are setting explicit targets for the expected penetration of electromobility in all three scenarios for the year 2030 based on our feasibility study - in the years to come, however, the further course of development will be a model endogenous decision.

The third scenario is "KLIMPLUS-LOW", the general conditions are identical to "KLIMPLUS", but a significantly delayed and/or slowed development of electromobility until 2030 (10% xEV market penetration in cars) is assumed and investigated.

2.2 The effects of electric mobility on the energy system

In the City of Stuttgart, around 250,000 to 300,000 cars have been registered over time. After 2020, there is a separation between the scenario realms. While in the "KLIM" scenario transport performance continues to rise, in the "KLIMPLUS" scenarios a trend reversal is discernible due to the shift to public transport.

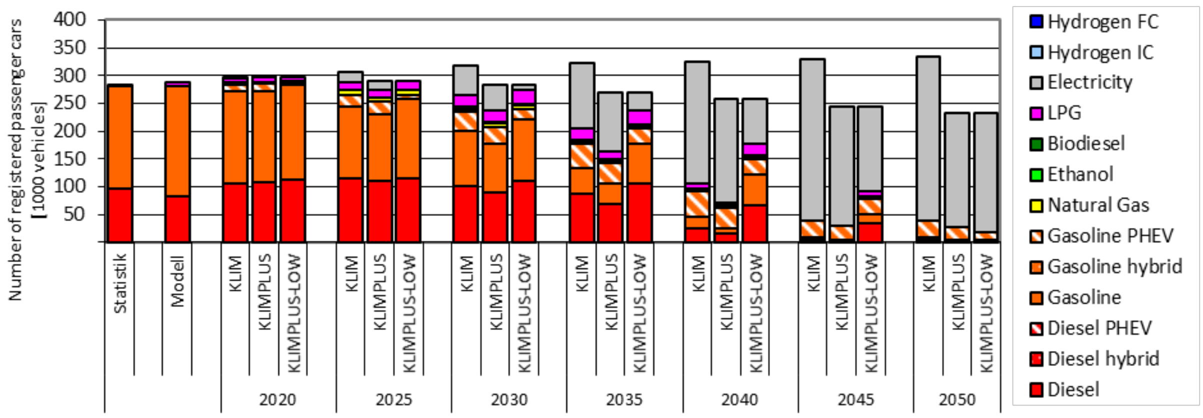

Figure 2: Registered passenger cars in the City of Stuttgart by drivetrain for different scenarios until 2050

In terms of the overall mix, gasoline and diesel-powered vehicles will dominate up to 2025. From this time on, however, BEV and PHEV will become increasingly important, with xEV accounting for up to 26% of the total vehicle base in 2030. From 2030 onwards, additional new registrations will be based almost entirely on BEV and PHEV vehicles.

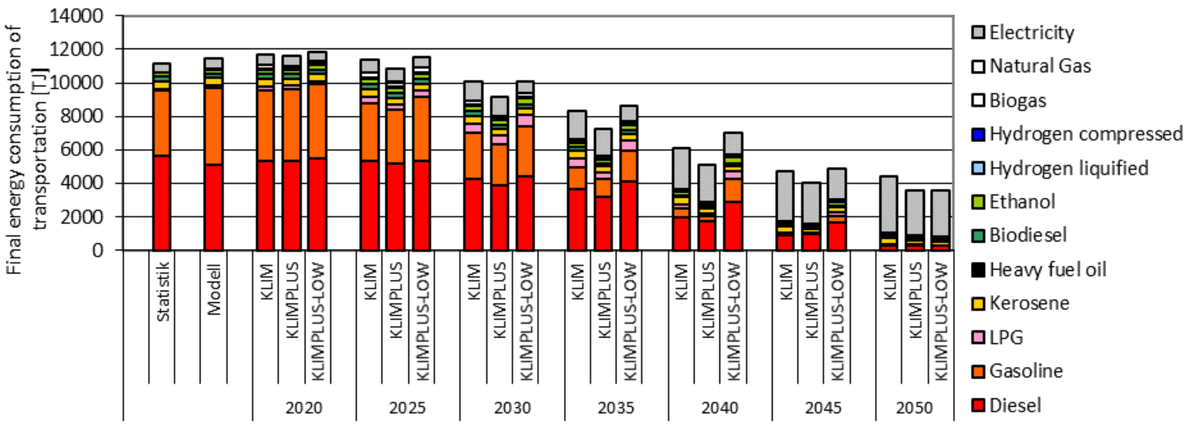

Figure 3: Final energy consumption of mobilized transportation in the City of Stuttgart over time

The final energy consumption of mobilized transportation will decrease from around 11,000 TJ per year in 2015 to about 4,000 TJ in 2050. This is primarily due to the fact that the initial dominance of diesel and gasoline will be replaced by electric mobility solutions after 2025, which will lead to a significant decline in consumption levels. This can be explained by the high efficiency of energy conversion in xEVcompared to combustion engines. In this context, it should be noted that ─ depending on the upstream chain of power generation ─ corresponding loss-making conversion steps can be transferred to the conversion sector. If we now take a closer look at the developments between the scenarios, very comparable conditions can be observed for the time points 2020 and 2050. In the intermediate periods however, the highest final energy consumption can be reliably located in the "KLIMPLUS-LOW" scenario. In contrast, the "KLIM" scenario has a lower energy consumption and a higher demand for mobility at the same time. This means that even if it is proving challenging to shift the modal split to public transport, electromobility could be an effective means of reducing energy consumption in the transport sector. The question of the repercussions on electricity generation and provision in the City of Stuttgart is derived from the increasing consumption of electricity as used for transportation and the rising share of this consumption with respect to final energy consumption.

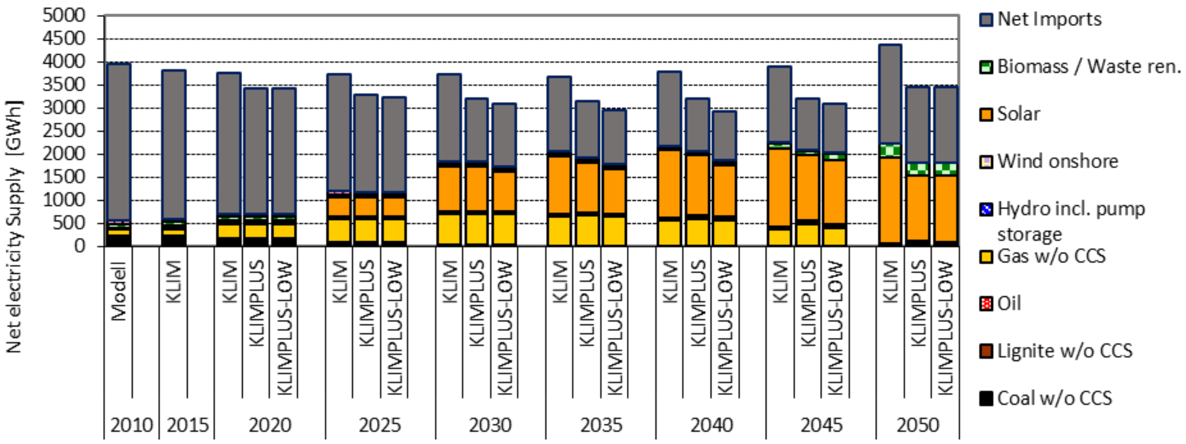

Figure 4: Electric power generation and imported electricity in the City of Stuttgart over time

Figure shows the development of electrical power supply over time. The demand for electricity will initially be met to about 85% through the import of electricity. Then the increase in predominantly roof-based photovoltaic systems will lead to a higher level of self-sufficiency for Stuttgart, with a correspondingly reduced dependency on imported electricity of less than 50% from 2035 to 2050. Natural gas CHP plants represent another valuable component of local power supply. From 2020 onwards, these will successively replace power generation from hard coal and are capable of generating both electricity and heat with low greenhouse gas emissions. After 2040, however, the window for these plants closes again, as the ambitious greenhouse gas reduction targets do not allow any margin for further emissions. In addition to further increases in production from photovoltaics and biomass, natural gas CHP plants will have to be replaced by increasing electricity imports. Overall, electric mobility will become ever more important in the context of electric power consumption, with corresponding repercussions for the provision of these quantities of electricity. This increased demand will compensate for the savings generated in other sectors and lead to a trend reversal in the development of electricity consumption after 2030.

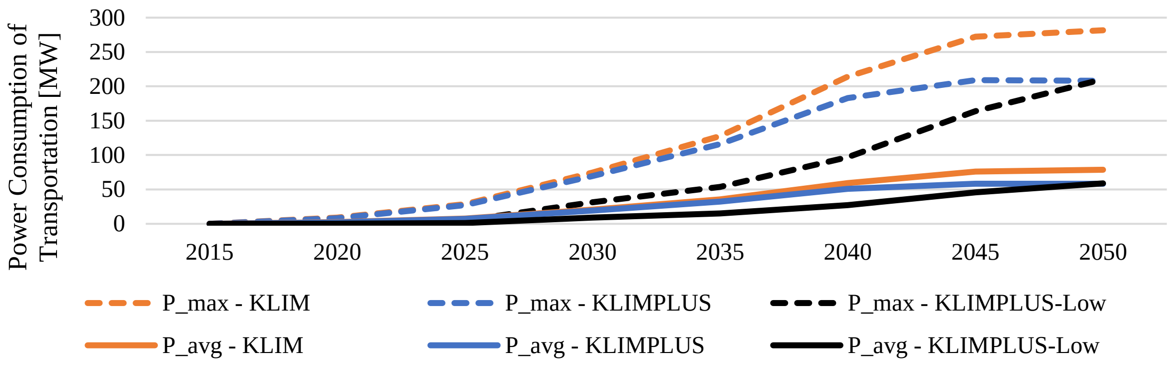

Figure 5: Average (P_Average) and maximum (P_Maximum) charging capacity of electric vehicles in the City of Stuttgart expressed in megawatts

Another output of the energy system model is the resulting charging capacity of xEV. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the development of average (P_Avg) and maximum charging power (P_Max) as a sum total for passenger cars, commercial vehicles and buses. The discrepancy between the annual average of charging power and the maximum is particularly important with regard to the maximum electric load in the Stuttgart Region. A saturation effect occurs in the scenarios with progressive electromobility penetration from 2045 onwards. The delayed ramp-up scenario, on the other hand, sees a further increase, but then reaches the same level as the "KLIMPLUS" scenario in 2050.

3 Microscopic travel demand modeling

3.1 Model description

To estimate the additional amount of energy needed by BEV in 2030, we simulate the travel behavior of people in the Stuttgart Region and the vehicle kilometer travelled in different scenarios with mobiTopp. mobiTopp is an agent-based travel-demand-model for the period of one week which was developed by the Institute for Transport Studies at Karlsruhe Institute of Technology (KIT). It consists of two partial models: the long-term and the short-term model [14]. The result of a simulation includes all trips for every person, respectively agent, in the planning area, based on an individual activity schedule.

Long-term model

The first part of the long-term model is to generate the population of the respective area (approx. 2.7 million in this study) including all characteristics that are constant for the entire simulation period. In the end, every agent is assigned to a household, has a fixed place of residence and if needed a fixed work or school location. Further, we model for every agent the possession of mobility tools e.g., car or transit pass ownership. In the case of cars, we distinguish between BEV and cars having an internal combustion (IC) engine. There are three segments of cars in every car type: small, midsized or big. In the context of this study, the modeling of BEV ownership is particularly relevant.

The BEV ownership model considers the compatibility of a person's travel behavior with BEV vehicle characteristics and a person's interest in new technologies such as BEV. The model is based on data from CUMILE (= Car Usage Model Integrating Long Distance Events) and the MINI E Berlin studies. A car owner’s travel behavior is particularly compatible with BEV if he or she drives often short distances and less than 12 times for journeys >90 km. Based on this group of people a logit model was developed to calculate the likelihood of suitability. Parameters in this model are gender, income, commuting distance, location of residence, number of cars in the household and household size.

To illustrate the interest of an agent in BEV in mobiTopp, a similarity measure was quantified based on the MINI E Berlin studies. This measure compares gender, age group, employment status, number of vehicles in the household, vehicle segment and commuting distance of the respective agent with the participants in the MINI E Berlin studies. As the similarity measure can take values in [0,1], it can be interpreted as a probability of interest. Multiplying both probabilities leads to the probability of BEV ownership on the part of an agent [15].

Short-term model

The short-term model simulates the activities of all agents in 1-minute increments chronologically and simultaneously over the period of an entire week. After each time increment, the model checks which agents have finished an activity. First, these agents are supposed to make a target selection for their following activity if the destination is not predefined (work, school or home). The destination choice model considers travel costs from the current location to the target cell, the distance to the next fixed point (home or work) and the attractiveness of the potential target cell. Second, these choose the mode of transport to get to their destination. The alternatives depend on their current location, the mode of transport previously used and the availability of cars in their household. The final decision is modeled using a multinomial logit and compares the benefits of the different transportation alternatives [14].

3.1.1 Basic Conditions

Before starting the simulations, we analyzed the existing public charging infrastructure in 2018 in this area and implemented it with the respective power (see [16],[17], [18], [19]). Other basic conditions for the simulation were defined at the specialist workshop together with experts from the automotive and energy industries. The main topics included the market penetration of BEV, the characteristics of the vehicles in the different segments and the characteristics of the charging infrastructure. The experts agreed on average characteristics for BEV as illustrated in Table 2. These parameters were constant for both simulation runs.

Table 2: Forecasts of average vehicle base parameters [20]

	Compact cars (A/B segment)	Mid-sized cars (C/D segment)	Large cars (E segment)
Distribution of BEV to segments	20%	55%	25%
Range [km]	250	350	550
Consumption [kWh/100 km]	12	17	23

There were bigger disagreements concerning market penetration, charging behavior and charging infrastructure. Therefore, we decided to vary the market penetration within the different simulation runs. In the first run, we supposed a market share of 30% (= 30%-simulation) and in the second 10% (= 10%-simulation). To ensure that the results of the cause-effect analysis can be easily interpreted, the parameters are varied "ceteris paribus". Most experts agreed that the number of charging points in the Stuttgart Region will increase by 2030, but there was a big uncertainty of the exact number and the location. To avoid a bias in the results based on the wrong positioning, we decided to assume that people can charge their car whenever their state of charge (SoC) is below 50%. This permits to identify areas with high energy demand.

3.1.2 Results

The whole Stuttgart Region made 51.79 million trips during the modeled week. Regarding the modal split and the share of km per transport mode, there are no substantial differences between the two simulations. We observe that the share of car trips in the City of Stuttgart is lower than in the rest of the region. Further analysis of car trips shows that BEV do 29.3% of all car trips (11.1% in 10%-simulation) but 40.5% of all car km (19.11% in 10%-simulation). This is already the first evidence that BEV are used for longer trips. Further analysis of car trips will prove this.

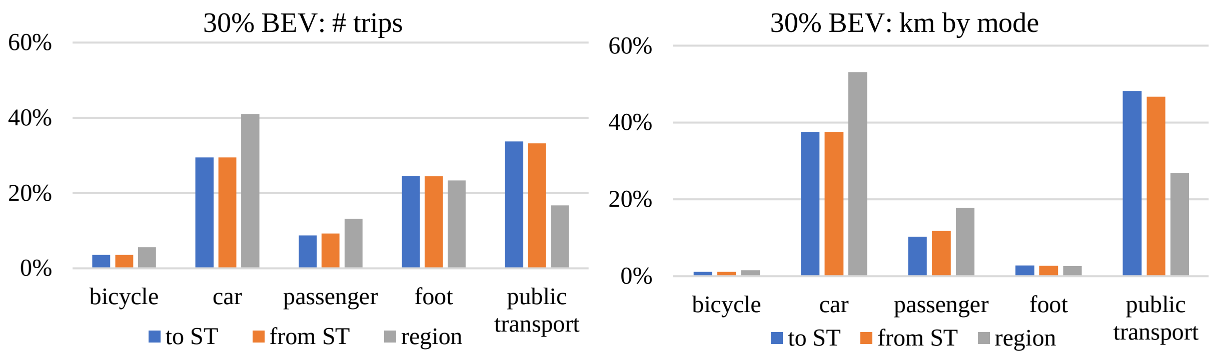

Figure 6: Modal Split for the 30% simulation

In both simulation runs the total number of cars in this area is around 1,38 million. Table 3 shows the distribution of cars for each type and segment in both simulation runs.

Table 3: Distribution of cars for each segment

	Compact cars	Mid-sized cars	Large cars	Total
30%-simulation				
BEV	6%	15%	8%	29%
IC Engine	16%	36%	19%	71%
10%-simulation				
BEV	2%	6%	3%	11%
IC Engine	20%	46%	23%	89%

The results from further car trip analysis (see Table 4), that BEV are used for longer distances than conventional cars with IC engine. The number of trips is similar.

Table 4: Average distance per trip and the average number of trips per week for each segment

	Compact cars	Mid-sized cars	Large cars
30%-simulation			
BEV	11.05 km per trip 15.69 trips/week	12.38 km per trip 15.96 trips/ week	13.03 km per trip 16.32 trips/ week
IC Engine	7.23 km per trip 15.67 trips/ week	7.46 km per trip 15.61 trips/week	7.80 km per trip 16.05 trips/week
10%-simulation			
BEV	13.41 km per trip 14.8 trips/week	15.28 km per trip 15.53 trips/week	16.18 km per trip 16.08 trips/week

IC Engine	7.74 km per trip 15.77 trips/week	8.02 km per trip 15.72 trips/week	8.40 km per trip 16.13 trips/week

Overall BEV charged 14,124 MWh during the week (6,705 MWh in 10%-simulation). In average, people charged their car 1.4 (large car) to 1.8 times (small car) per week (1.5-1.9 in 10%-simulation). Large cars charged averagely 52.9 kWh, midsized cars 28.2 kWh and small cars 15 kWh (54.3 kWh/ 28.9 kWh/ 15.3 kWh in 10%-simulation). Figure 7 illustrates the energy per build-up area [kWh/km²].

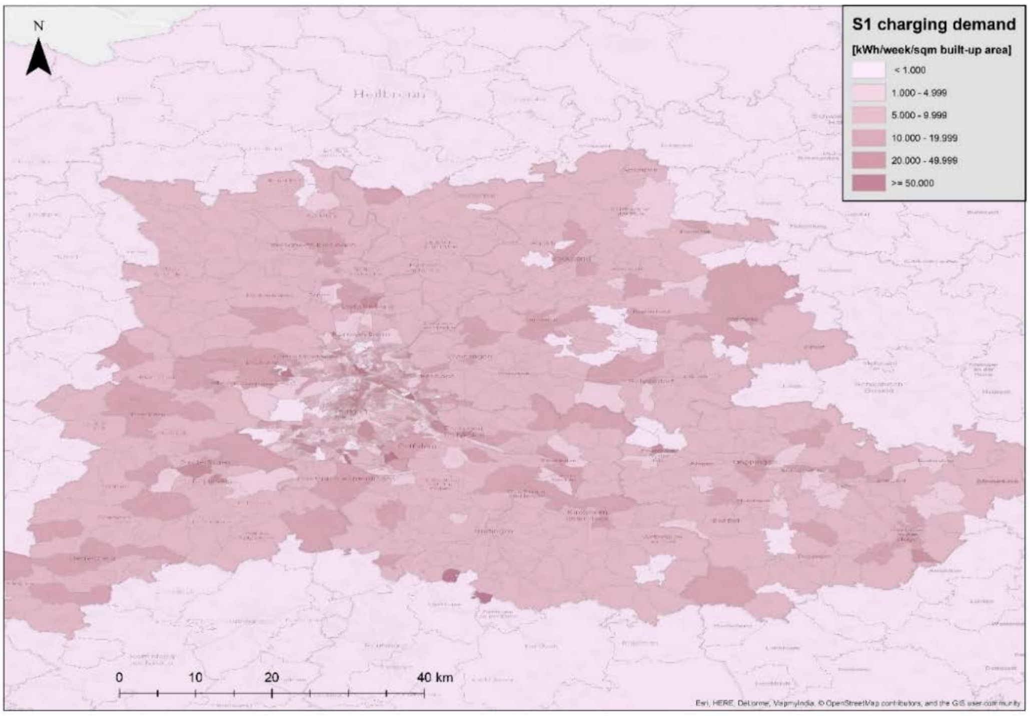

Figure 7: Cumulated charged energy during the modeled week

For further analysis presented in the following chapter four, we focused on residential areas, because of the real electricity grid characteristics. We selected a zone with 779 agents living in 433 households (single- as well as apartment houses). In total, those agents owned 359 cars, 83 of them were BEV (only 29 in 10%-simulation). We assumed that as soon as people come home they charge their car. This resulted in an energy demand of 1,926 kWh per week (815 kWh in 10%-simulation).

4 Coupling traffic models with load flow calculations of the electricity network (example model coupling with mobiTopp and MATPOWER)

In the following the results on mobility patterns from the microscopic traffic demand model mobiTopp (see chapter 3.1.) and the resulting energy demand from EV are linked to the load flow calculation by MATPOWER [21]. MATPOWER is an open-source package based on MATLAB technology for solving steady-state simulation and optimization problems. Herewith, a coupling of a specific traffic demand model with a concrete load flow calculation is a novelty for literature. The combination of traffic model and load flow calculations allows a profound analysis of impacts from xEV on the voltage retention in the electricity grid and the utilization of operative grid components such as transformers and lines. For the further grid analysis, the network area under consideration is located in the aforementioned particular zone and comprises

349 households (allocated in single-family, two-family and multi-family houses). Therefore, all results generated by the mobiTopp model are adjusted according to the number of households.

Within the load flow analysis, four scenarios are considered. In addition to the two simulations presented above with the assumed market penetrations of 10% and 30%, a low (3.7 kW) and a high (11 kW) charging rate are assumed for each penetration. This results in the scenarios presented in Table 5.

Table 5: Considered scenarios

Scenario	Penetration	Charging rate [kW]
1a	10%	3.7
1b	10%	11
2a	30%	3.7
2b	30%	11

Based on the assumption of uncontrolled charging, individual charging profiles are generated by the mobiTopp model within the investigated zone. The adjusted individual charging profiles are then aggregated within the modeled week in an hourly resolution (Figure 8). The patterns differ depending on the scenarios and reflect the charging behavior in the related zone. The additional energy demand from BEV amounts to 815 kWh (10% market penetration) or 1,926 kWh (30% market penetration) per week.

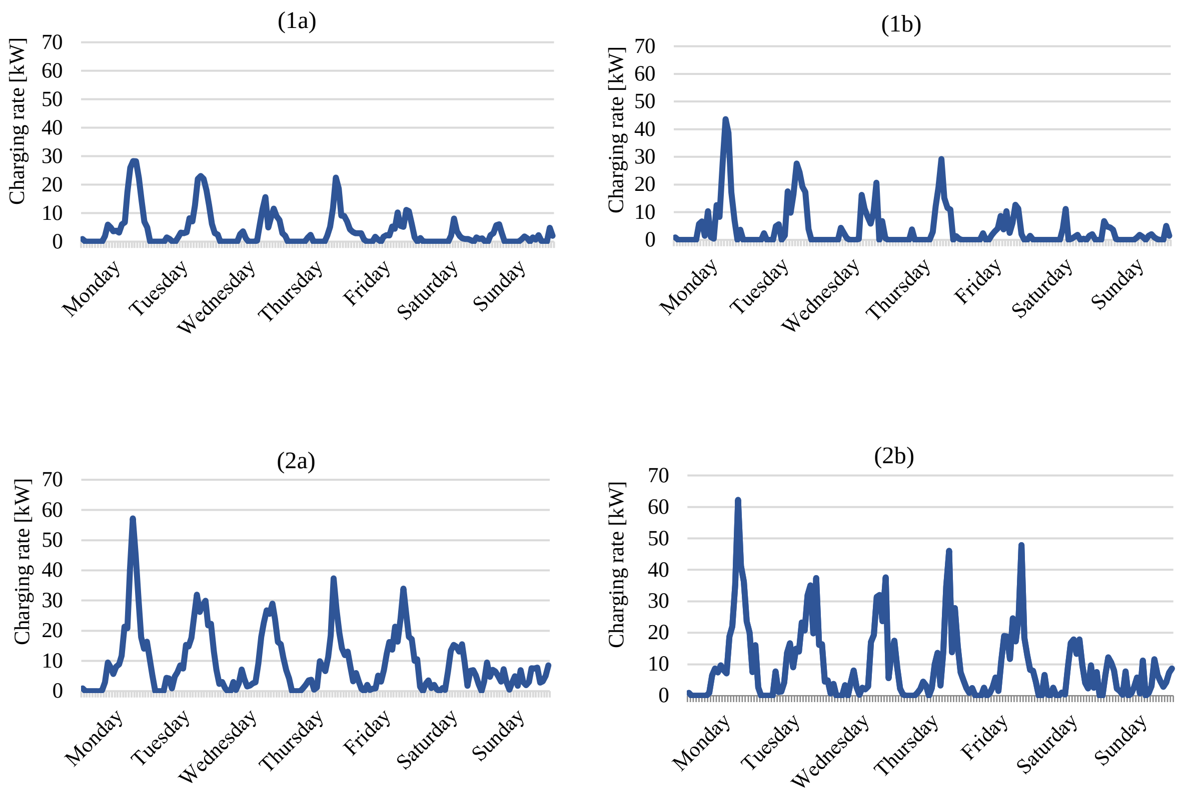

Figure 8: Load patterns within the modeled week for all scenarios (1a-2b)

For stationary load flow analysis only the peak load is decisive. In order to identify this peak within the modeled week, the total network load must first be determined and consists of the household load plus the load caused by the charging processes of the BEV. The following aggregated load profile for the 349 households is based on [22], [23] and is generated on a stochastic basis including year-specific lighting and heating and is illustrated in Figure 9.

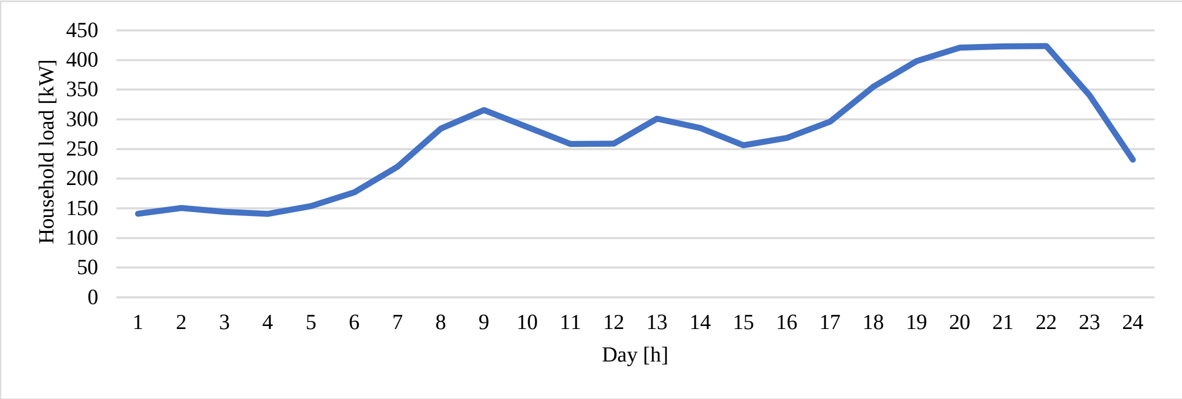

Figure 9: Aggregated household load curve for a working day in winter

It can be observed that the already existing household peak load lies in the evening hours. Based on the total network load, the peak loads shown in Table 6 are obtained for the different scenarios. These explicitly include the individual driving and charging behavior generated by the mobiTopp model.

Table 6: Peak load in the related scenario

Scenario	Peak load [kW]
1a	449
1b	438
2a	465
2b	457

It is noticeable that, taking into account the higher charging rate (scenario 1b and 2b), the peak load is reduced compared to the scenarios with a lower charging rate. This is a contradiction to most other results from literature and can be explained by the fact that in our case the peak loads of households and charging processes fall apart over time and the arrival times are comparatively widely distributed (i.e. faster charging leads in our case to a reduction of parallel charging).

In order to take also into account the specific network topology, the grid data and the related technical restrictions (voltage limits, maximum transformer and cable capacity) are integrated into MATPOWER. To link the above presented load patterns to the load flow analysis, the peak load is distributed equally among all households in the network.

5 Load flow analysis – first results

A load flow analysis is applied to investigate the network effects resulting from the charging processes of BEV. Since uncontrolled charging can lead to concentrated peaks in the BEV load during the already existing peak load of residentials at evening hours, new challenges can arise, especially for the distribution network

[24]. The simultaneous consideration of the individual charging behavior in the selected zone and the associated network topology enables a profound analysis of the effects on the voltage retention in the grid and on the utilization of operative network components such as transformers and cables. Therefore, within the scope of the load flow analysis, the network is examined with regard to transformer and cable utilization as well as the minimum voltage level in the grid. For the applied stationary load flow analysis only the peak load is considered.

Figure 10 shows the transformer utilization for all scenarios. If no xEV is integrated in the grid, it is used at 84% capacity. If a market penetration of 10% or 30% of xEV is taken into account, the transformer utilization increases to 89% (scenario 1a), 86% (scenario 1b), 92% (scenario 2a), and 90% (scenario 2b), respectively. But independent of the scenario, no overload of the transformer appears.

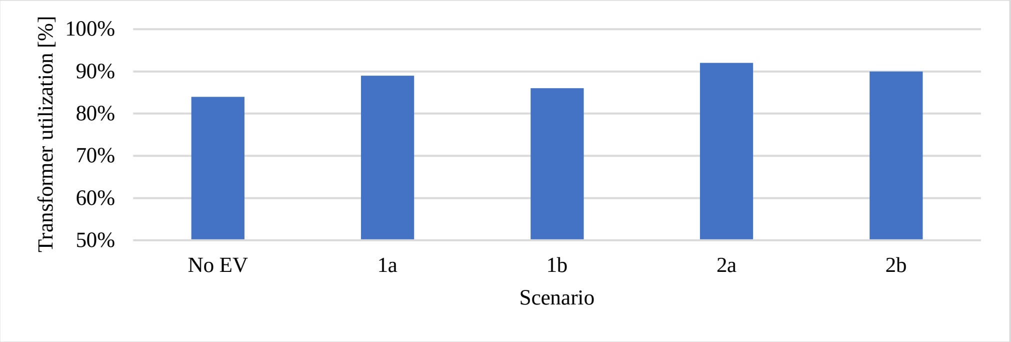

Figure 10: Transformer utilization for the different scenarios

In order to ensure network stability, voltage drops have to be avoided. With regard to the minimum voltage level in the network section, the network is not facing critical situations in any of the scenarios. The minimum voltage level decreases slightly due to the additional load from xEV. However, there is no danger to the lower voltage limit. Finally, the maximum cable utilization is investigated. Taking xEV into account, the maximum cable utilization increases from 52% (without xEV) to 61% (scenario 1a), 59% (scenario 1b), 68% (scenario 2a), and 64% (scenario 2b), respectively. Regardless the scenario considered, the maximum cable capacity is not exceeded.

In summary, it can be stated that no thermal or voltage related limits are exceeded. Therefore, no critical grid situations are caused by xEV in the investigated network section. Also severe impacts on higher grid levels are unlikely [25]. By taking into account the individual charging profiles generated by the mobiTopp model, it could be shown that consideration of the simultaneity of the charging processes has a decisive impact. As shown in the load flow analysis, in our case higher charging rates are more advantageous due to the different temporal distribution of the peak loads of households and charging processes and the comparatively widely distributed arrival times. Therefore, even a market penetration of 30% with a charging rate of 11 kW does not lead to limit value violations in the grid. But since low-voltage distribution grids are very heterogeneous, no generalizing statement should be made.

6 Conclusion

Individual mobility tends within the next ten years significantly from conventional towards electrified propulsion. Based on this study, it is assumed in the case of Germany from currently 0.5% ratio for xEV's towards up to 27% till 2030. Taking into account the changes on primary energy demands of all sectors (industry, households, mobility) the current simulation indicate that it may be possible to keep the total energy demand of an urban area on the same level (or lower) than today. Nevertheless, partial energy demands driven by the mobility demands may lead to local disturbances in the energy distribution grid.

Based on a traffic demand model it was therefore analysed for the Stuttgart region, at which level and which local area particular higher energy demands may occur due to the recharging of xEV. The particular higher energy demand in the rural areas of Stuttgart can be stated as a one result on these investigations, which may be explained by the parameters of the traffic demand model which supports xEV-use preferred for long distance trips.

Given these results (i.e. local energy demands), a detailed analyse on the energy load flow of was conducted for residential areas, taking into account the specific network topologies. But by applying four different scenarios (low / high charging power, low / high xEV ratio) on one specific residential area, none of thermal or voltage limit was exceeded. These results need to be continued in order to match these research results with all other areas of the Stuttgart region, since low-voltage distribution grids are very heterogeneous, and therefore no generalizing statement should be made.

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