ORGANIZNG E-MOBILITY IN CITIES – CHANCES AND RISKS

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ABSTRACT

In this paper we explore the preconditions and requirements in order to enable the renewal of the vehicle fleet towards e-cars without weakening eco-mobility (public transport, biking, walking). We follow a linked approach of arranging charging infrastructure and regulating the parking spaces. We analyze the results of this approach by modeling different scenarios for the case study city of Vienna with the LUTI (land-use transport interaction) model MARS (Metropolitan Activity Relocation Simulator). Four different policy scenarios are modeled and the results compared. We look at changes in transport behavior (modal split and vehicle kilometers), the emissions resulting out of the different policies and the impact on public transport ridership.

1. INTRODUCTION

E-mobility is currently facing a promising boom, which readjusts both the requirements and possibilities of organizing a future transport system. The chances of individual e-mobility to reach certain transport policy goals are obvious – minor dependency on fossil fuels and the reduction of greenhouse gases and air pollutants. However, lower user-specific operational expenses, exceptions from environment-based cordons of certain classes of vehicles (low-emission-zones, etc.) and the omission of "environmental reasoning" for certain user groups can lead to counterproductive system effects and a net-growth of private motorized transport (PMT).
Especially city-specific problems of PMT like land consumption and congestion cannot be solved by e-mobility. Thus, a large-scale establishment of e-cars in cities has to be planned and operated comprehensively under consideration of certain basic conditions. Various urban administration authorities have set themselves objectives such as the strengthening of public and non-motorized transport.
We show which kind of organizational structures are necessary to enable the renewal of the vehicle fleet towards e-cars without weakening public transport, cyclists and pedestrians.
Section 2 provides the method of the analysis with a short description of the models used. In the next section (3) the four policy scenarios are described shortly, their settings and underlying background scenarios are given in section 4. A comprehensive description of the policy scenarios is provided in section 5. The results in section 7 are compared with the objectives of the transport master plan of Vienna (section 6). We close by summing up the results of this analysis in section 8.

2. METHOD

The analysis was carried out with three models. Two models (SERAPIS) served for calculating the fleet composition for conventional, hybrid (in the following named as cars) and electric vehicles (e-cars) for the city of Vienna and the hinterland. With the transport-land use model (MARS) the traffic behavior in the model region was simulated. The MARS model was connected to SERAPIS via two variables: the operating costs, calculated in MARS, served as input variable for the SERAPIS models; the fleet development as an output of SERAPIS served as input for MARS.

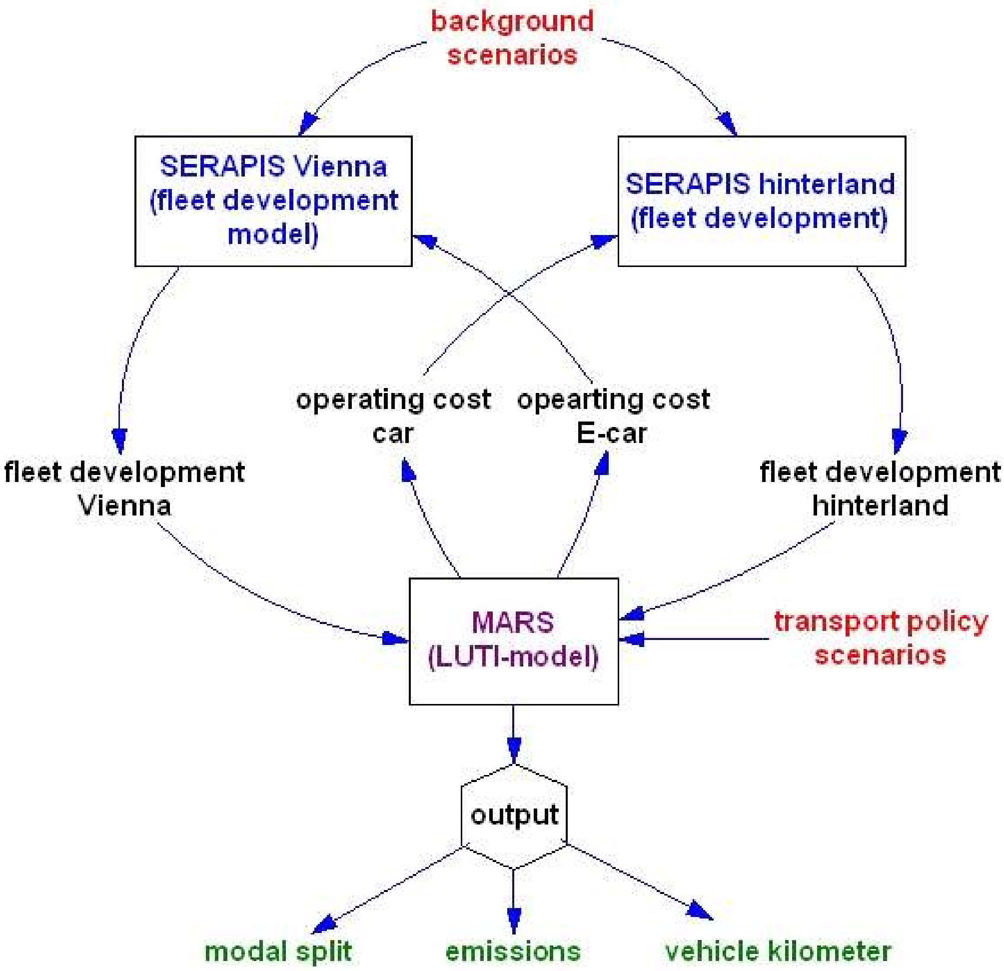

Figure 1 – Links of the three models and external input

A comprehensive data analysis built the basis for the model building process. The data basis covers demographical data for the case study area, transport relevant data (level of motorization, modal split, etc.) and transport policy goals.
After the adaption process of the three models to the current data set we designed the different scenarios and performed the model runs. In this paper we describe and present five different scenarios. The scenarios where influenced by the transport policies of the city council. The output of the different policy runs will be described trough traffic behavior variables like modal split and vehicle kilometers as well as the changes in CO_2 emissions.

2.1. SERAPIS

SERAPIS (Simulating the Emergence of Relevant Alternative Propulsion technologies in the car and motorcycle fleet Including energy Supply) is a model which was developed at the Austrian Energy Agency. It is a dynamic model that simulates the fleet development, the shares of the different propulsion technologies, hence the demands for the electricity economy and the potentials for reducing CO_2-emissions.
SERAPIS consists of the following 5 modules:

- Calculation of the development of the number of cars and single-lane vehicles.
- Calculation of the choice of the propulsion technology for cars and single-lane vehicles.
- Calculation of the additional electricity demand for e-mobility.
- Calculation of the demand for the electricity production out of renewable resources.
- Calculation of the CO_2-emissions.

2.2. MARS

The MARS (Metropolitan Activity Relocation Simulator) model was developed at the Research Center of Transport Planning and Traffic Engineering at Vienna University of Technology. The first Vienna model was built in 1997 [1] and has been expanded and adapted to new data regularly. It is a Land-Use Transport interaction model which simulates the mutual interactions between the land-use and the transport system. To date it has been applied to 15 different cities over the world [2-3]. Recently it was set up also for a national case study of Austria [4]. The model zones from the model described in this paper cover the 23 Viennese districts and the Vienna hinterland.

3. SCENARIO OVERVIEW

Beside the extrapolation of status quo and existing trends of relevant traffic indicators, we designed two different transport policy scenarios (E-car, Equidistance). Each scenario is based on certain background scenarios. These cover the development of crude oil price and subsidies for e-cars as well as different fleet developments for e-cars. We combined the transport policy scenarios with different background scenarios in order to define and model four policy runs.
In this paper we present the following scenarios with their results:

- Business as usual (BAU)
- E-Car+
- Equidistance
- Equidistance + E-car

Table 1 shows the assumptions for our four scenarios (subsidies for e-cars, transport policy of the city of Vienna).

Table 1– Scenario setting in Vienna

Scenario			BAU	E-car+	Equidistance	Equidistance + E-car
Sub-sidies	funding for e-cars	low	X		X	
		high		X		X
Transport Policies	density of charging stations	low	X		X	X
		high		X		
	availability of public parking spaces	low			X	X
		high	X	X		
	parking fees for e-cars	yes	X		X	X
		no		X		
	fuel duty	low	X	X		
		high			X	X

4. BACKGROUND SCENARIOS

4.1. Crude oil price

In this paper we assume a progressive increase of the crude oil price until the year 2030. Compared to the base year 2010 the price will double. Figure 2 compares our assumed crude oil price development with several studies and projects.

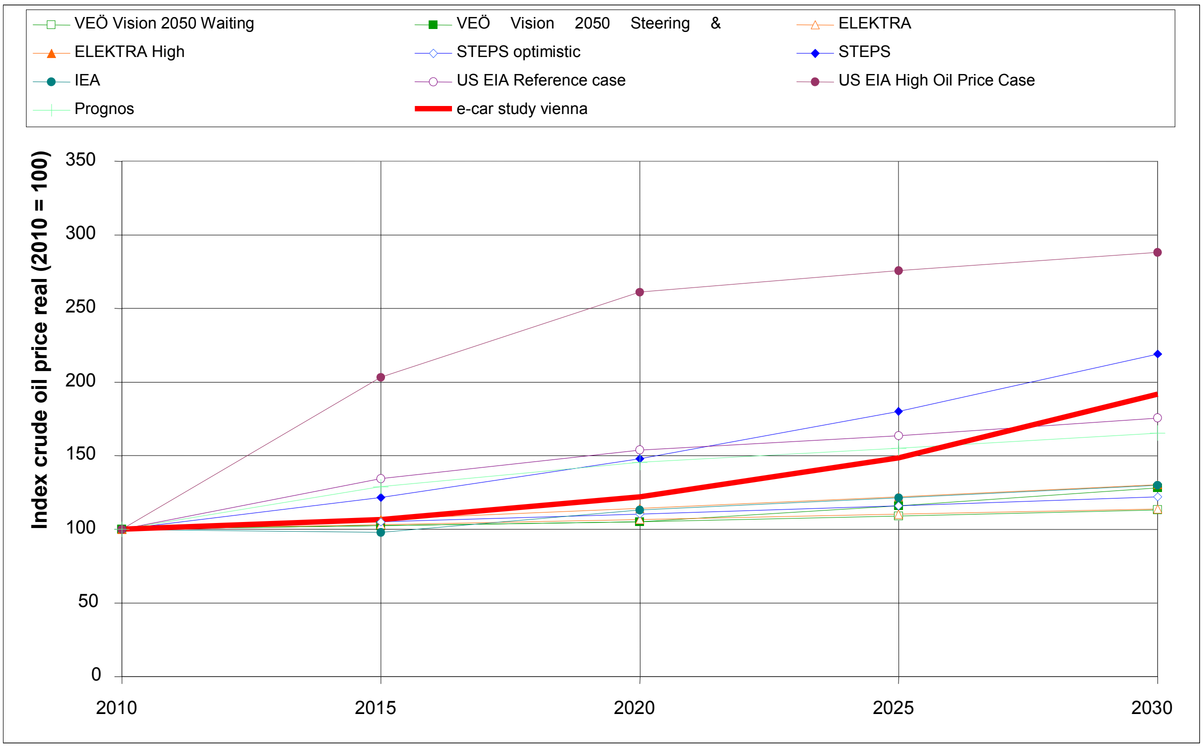

Figure 2 – Development of the crude oil price

4.2. Fuel duty

For the first two scenarios (BAU, E-Car+) the fuel duty equals the current level in Austria (0.43 EUR/liter for petrol, 0.30 EUR/liter for diesel) and remains constant. In both equidistance scenarios (Equidistance, Equidistance + E-car+) the fuel duty increases constantly over time up to +30 % in the year 2030 (0.59 EUR/liter for petrol, 0.41 EUR/liter for diesel).

4.3. Subsidies for e-cars

We differentiate the level of subsidies for e-cars between the E-car+ and the Equidistance scenarios. In the E-car+ scenario the subsidies increase rapidly in the first year to 5,000 EUR/vehicle and then decrease until the year 2021. Further we distinguish between the development of the gross and net purchase prices of e-cars. The net purchase price does not regard differences by sales tax, engine related insurance tax and standard fuel consumption tax.

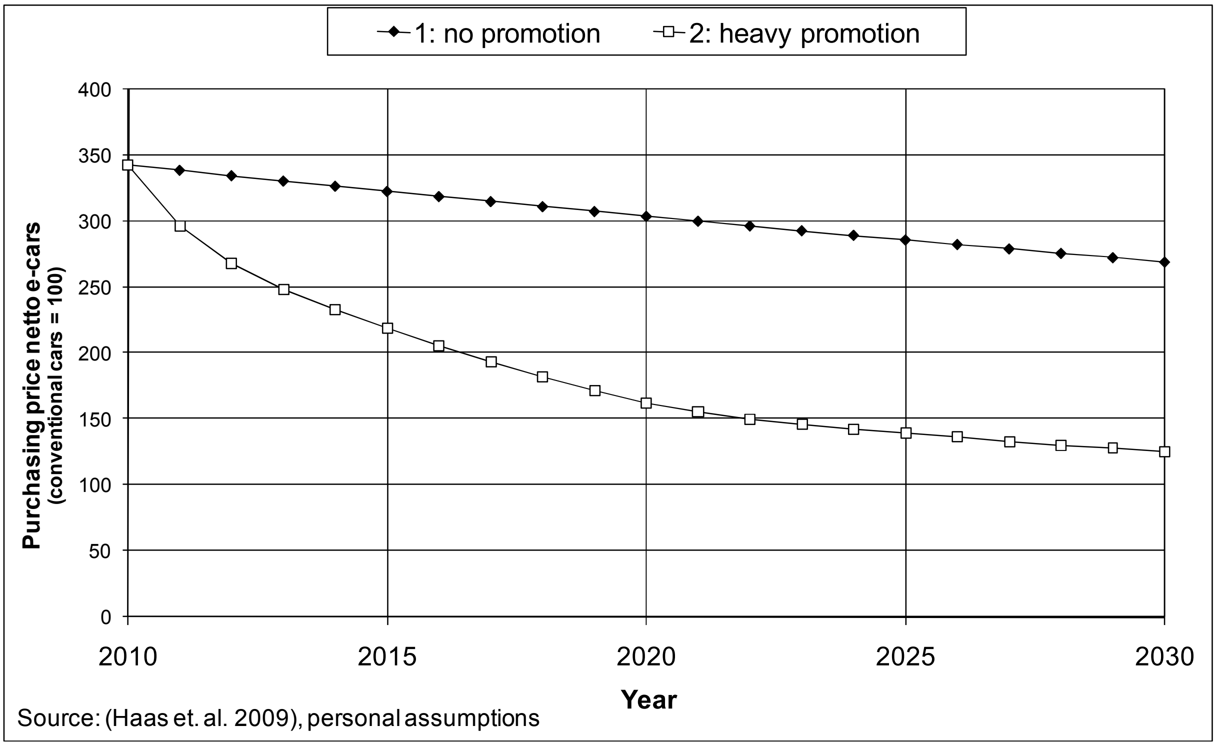

Figure 3 – development of the purchasing price for e-cars

5. TRANSPORT POLICIES

As mentioned in section 3 we modeled four different scenarios varying in the following parameters:

- Spatial arrangement of the charging infrastructure and parking places for e-cars.
- Walking time from trip origin to the charging stations, respectively the parking place.
- Parking fees (level and location).
- Fuel duty.

Each scenario was calculated separately for e-cars and cars for the case study area of Vienna and its hinterland.

Tables 2 to 5 give an overview of the different settings for each scenario.
In their first row the spatial arrangement (density) of the charging stations respectively the parking places is given. Either parking in public space is allowed and possible (under regard of parking fees) or parking is organized in collective parking garages (owned by the local authority) which serve as charging stations.

These structural conditions determine the walking time to the parking place of the origin and destination zones, which is shown in the second row. They can be very high or high (about 3-5 minutes to common garages and garages with charging infrastructure for e-cars in inner city districts), middle (about 1 minute in average to parking places in public space) or marginal (0.5 minutes or below when parking on private land in the suburban settlements). The varying walking times to and from the parking place take into account the structural differences between the urban area where parking is mostly possible in public space and the suburban hinterland where most parking places are privately owned.
The third row contains the design of parking fees, including the charged areas and the level of charges for Vienna and its hinterlands. In the last row the level of fuel duty is given. The first value is the fuel duty for diesel cars the second for cars.

5.1. BAU scenario

The BAU scenario extrapolates the current development. No massive infrastructure changes are considered. The charging infrastructure for e-cars in Vienna is organized in collective parking garages with a low density. Charging infrastructure in public streets is not provided in this scenario. In comparison to conventional cars the walking time to charging & parking places for e-cars is therefore very high. Both, e-cars and conventional cars need to pay inner city district parking fees.

Table 2 - BAU scenario settings

Basic parameters / Scenario		Business as usual (BAU)	
		e-cars	cars
Density of charging stations/availability of parking places	Vienna	charging in collective garages or at parking places - low percentage < 5 %	parking in the streets / garages status quo
	Urban hinterland	charging possibility – private parking place	private parking place
Walking time to charging station / parking place	Vienna	very high (about 5 min.)	middle (about 1min.)
	Urban hinterland	low (about 0.5 min.)	low (about 0.5 min.)
Parking fees (short/long-term parking)	Vienna	parking space control status quo	parking space control status quo
	Urban hinterland	no parking fees	no parking fees
Fuel duty	Vienna	no	0.30 resp. 0.43 EUR/Liter
	Urban hinterland	no	0.30 resp. 0.43 EUR/Liter

5.2. E-car+ scenario

The E-car+ scenario is based on a strong increase in the density of charging infrastructure in public spaces. Therefore the walking times from trip origin to the charging infrastructure alternatively to the parking place for e-cars is equal to the access time for cars. Parking for e-cars is free (the parking fees in parking garages are reduced) and no taxes similar to the fuel tax are levied.

Table 3 - E-car+ scenario settings

Basic parameters/ Scenario		E-car+	
		e-cars	cars
Density of charging stations / availability of parking places	Vienna	charging in collective garages or at parking places - percentage > 30 %	parking in streets / garages status quo
	Urban hinterland	charging possibility - private parking place	private parking place
Walking time to charging station / parking place	Vienna	middle (about 1min.)	middle (about 1min.)
	Urban hinterland	low (about 0.5 min.)	low (about 0.5 min.)
Parking fees (short/long-term parking)	Vienna	no parking fees / reduced rates	parking space control status quo
	Urban hinterland	no parking fees	no parking fees
Fuel duty	Vienna	no	0.30 resp. 0.43 EUR/Liter
	Urban hinterland	no	0.30 resp. 0.43 EUR/Liter

5.3. Equidistance scenarios

5.3.1 *Principle of equidistance*

Pedestrians act in their walking behavior according to a certain function of attractiveness [5]. Short walks offer 100 % attractiveness, longer walks have far less. Pedestrians assess time subjectively and therefore value their walks considering their surrounding areas.
Walther [6] found, that the access walks of pedestrians to public transport stops, and the access and egress times to parking places of cars play an important role in transport mode choice. Humans do not perceive an increase of the access or the egress time linearly but exponentially. The longer these access and egress paths are, the manifold they are perceived.
If it is possible to park a car in the basement parking garage of one's house, or in the public space directly in front of one's home or work, the car presents a 100 % attractive accessibility. A public transport stop 400 meters away holds less than 20 % of attractiveness in inner city surroundings. Thus people are going to prefer their car, if somehow possible.
To create equal opportunity conditions between car and public transport equidistance between the parked car and the next public transport station of for all activities is necessary.

Cars and other PMT (private motorized traffic) need to be parked in centrally organized parking garages distributed over the city, resulting in at least a distance equal to the distance of frequently operating public transport stops.

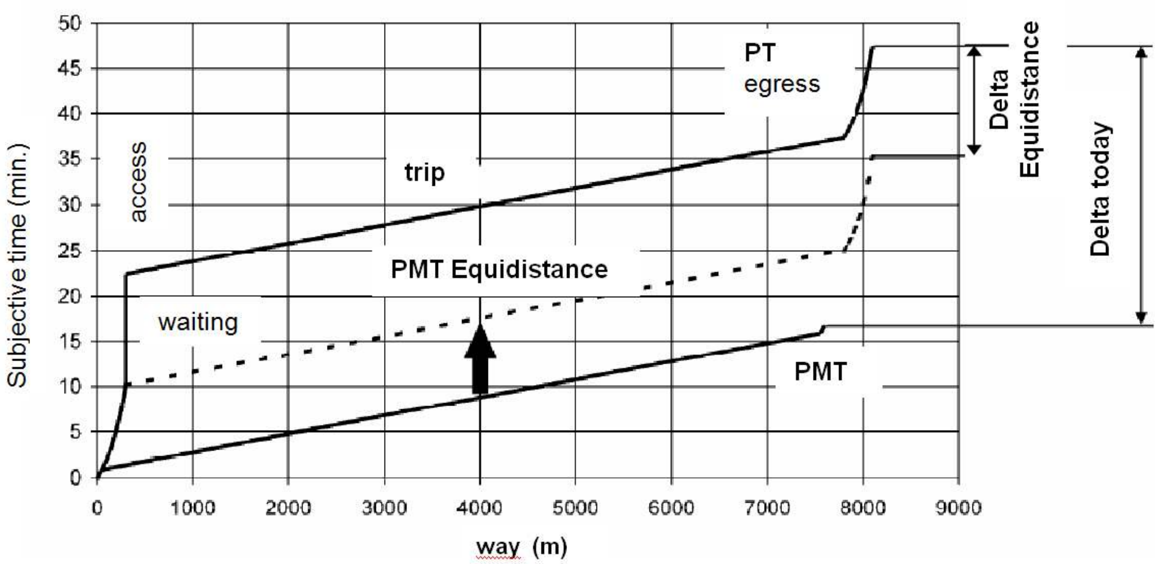

Figure 4 – subjective valuated walking times in PT (public transport) and PMT.

5.3.2 *Equidistance scenario*

In the Equidistance scenario the charging and parking for e-cars and parking cars are organized in collective parking garages. Thereby the access time (walking) is increased to 3 minutes in the city. The scenario is based on the fact that in the surroundings of Vienna people can park and charge their car nearby their house or their apartment. The access time is in accordance to the previous described scenarios short (about 0.5 minutes).

The level of the parking fees for e-cars does not differ from the E-car+ scenario. Parking fees for cars are increased and have to be paid city-wide.

The fuel duty is increasing over time until the year 2030 (+30 % of the base value). The fuel duty is not assigned to e-cars, a similar energy consumption tax for e-cars is not implemented.

Table 4 – Equidistance settings

Basic parameters/ Scenario		Equidistance	
		e-cars	cars
Density of charging stations / availability of parking places	Vienna	charging in collective garages or at parking areas - percentage > 5 % parking in collective-garages	parking in collective garages
	Urban hinterland	charging possibility – private parking place	private parking place
Walking time to charging station / parking place	Vienna	high (about 3 min.)	high (about 3 min.)
	Urban hinterland	low (about 0.5 min.)	low (about 0.5 min.)
Parking fees (short/long-term parking)	Vienna	commercial control over parking space area-wide in Vienna; increase of parking fees until 2020	commercial control over parking space area-wide in Vienna; increase of parking fees until 2020
	Urban hinterland	no parking fees	no parking fees
Fuel duty	Vienna	no	base value 2010 +30 % until 2030
	Urban hinterland	no	base value 2010 +30 % until 2030

5.3.3 *Equidistance + E-car+ scenario*

There are only two major differences between the Equidistance and the Equidistance + E-car+ scenario:

1. The number of e-cars in the system is higher due to higher subsidies.
2. The organizational form for parking/charging space is equal (collective parking garages) but more garages are equipped with charging possibilities in this scenario.

The other settings remain the same.

Table 5 - Equidistance + E-car+ settings

Basic parameters/ Scenario		Equidistance + E-car+	
		e-cars	cars
Density of charging stations /availability of parking places	Vienna	charging in collective garages or at parking areas - percentage > 30 % parking in collective garages	parking in collective garages
	Urban hinterland	charging possibility - private parking place	private parking place
Walking time to charging station / parking place	Vienna	high (about 3 min.)	high (about 3 min.)
	Urban hinterland	low (about 0.5 min.)	low (about 0.5 min.)
Parking fees (short/long-term parking)	Vienna	commercial control over parking space area-wide in Vienna; increase of parking fees until 2020	commercial control over parking space area-wide in Vienna; increase of parking fees until 2020
	Urban hinterland	no parking fees	no parking fees
Fuel duty	Vienna	no	base value 2010 +30 % until 2030
	Urban hinterland	no	base value 2010 +30 % until 2030

6. EVALUATION OF THE RESULTS

The scenarios were modeled under consideration of the transport policy goals of the city of Vienna for the year 2020. Although MARS is a dynamic simulation model, which can depict each variable at each point in time, we show just the results for the years 2020 and 2030.

The Vienna transport master plan defines the following modal split objectives for Vienna in the year 2020:

- Reduction of PMT trips to 25 % of all trips.
- Increase in bicycle share to 8 % as quickly as possible.
- Increase in public transport share from 34 % to 40 %.
- For commuting flows from the Vienna hinterland the distribution between public transport and PMT should shift from 35 % / 65 % to 45 % / 55 %.

7. RESULTS

We analyzed the results of the scenarios concerning the changes in transport behavior by looking at the changes in modal split and vehicle kilometers for all scenarios.
MARS is primarily a model that covers commuting travel. Other trip purposes such as leisure, shopping, visiting friends, etc. are summarized together to one other trip purpose. The following figures therefore take into account all trip purposes.

The environmental impacts are presented in terms of nitrogen oxide (NO_x), particulate matter and carbon dioxide emissions. These variables are presented for people living in Vienna and in-commuters to Vienna.

7.1. Changes in transport behavior

The scenario E-car+ shows no relevant change in transport behavior compared to the BAU scenario. Some car user switch to e-cars, but the share of public transport users, pedestrians and cyclists stays constant. The sole increase in funding of e-cars without changing the organizational structures for parking does not change the modal split very much (see Figure 5).

The scenarios Equidistance and Equidistance + E-Car+ show crucial changes. Figures 5 and 6 depict the modal split for the year 2020 and 2030 in Vienna. The combination of equidistance with an increased funding of e-cars is the most effective way of changing transport behavior.

The modeled measures in these two scenarios also enable the achievement of the transport political objectives of Vienna. Basically shifts from car to public transport occur.

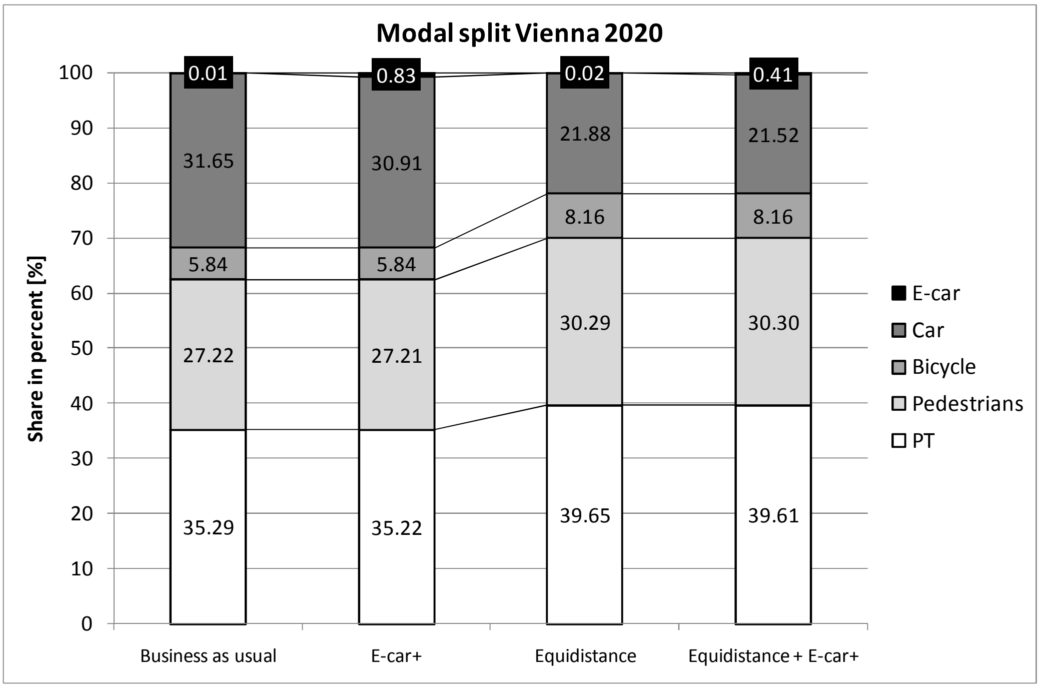

Figure 5 - Modal split Vienna 2020 - comparison of the scenarios

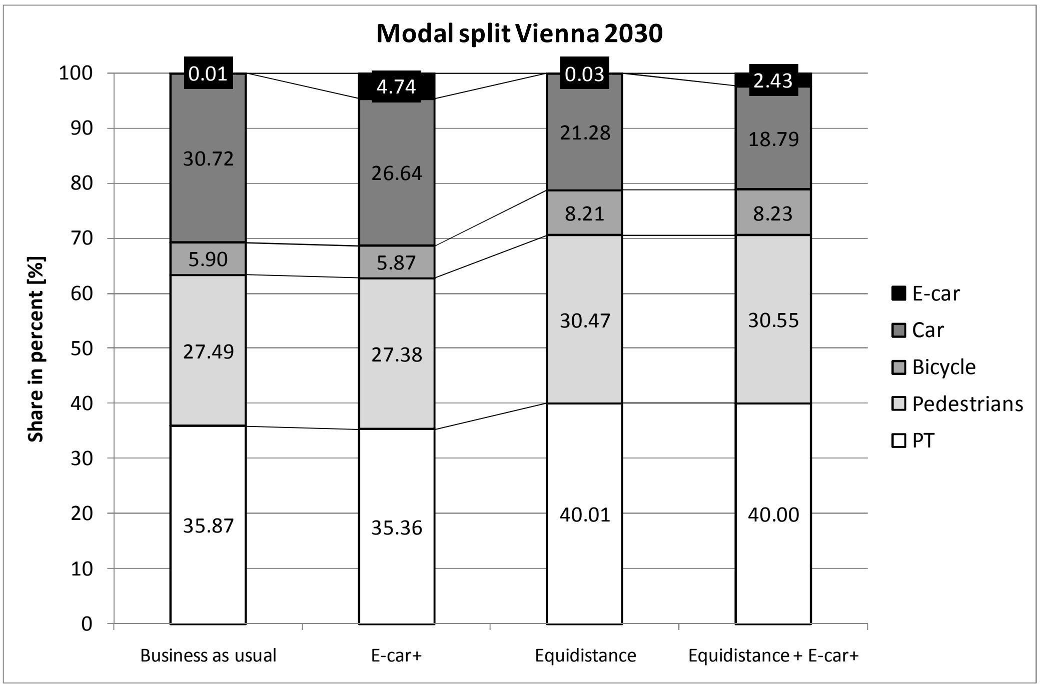

Figure 6 – Modal split Vienna 2030 – comparison of all scenarios

The picture looks somehow different for the in-commuters. Many people living in Vienna's hinterland have the possibility to park their car or e-car near their home respectively on private ground. Due to the policy that only destination locations in Vienna include a charged parking organization the modal split changes are modest (see Figure 7).

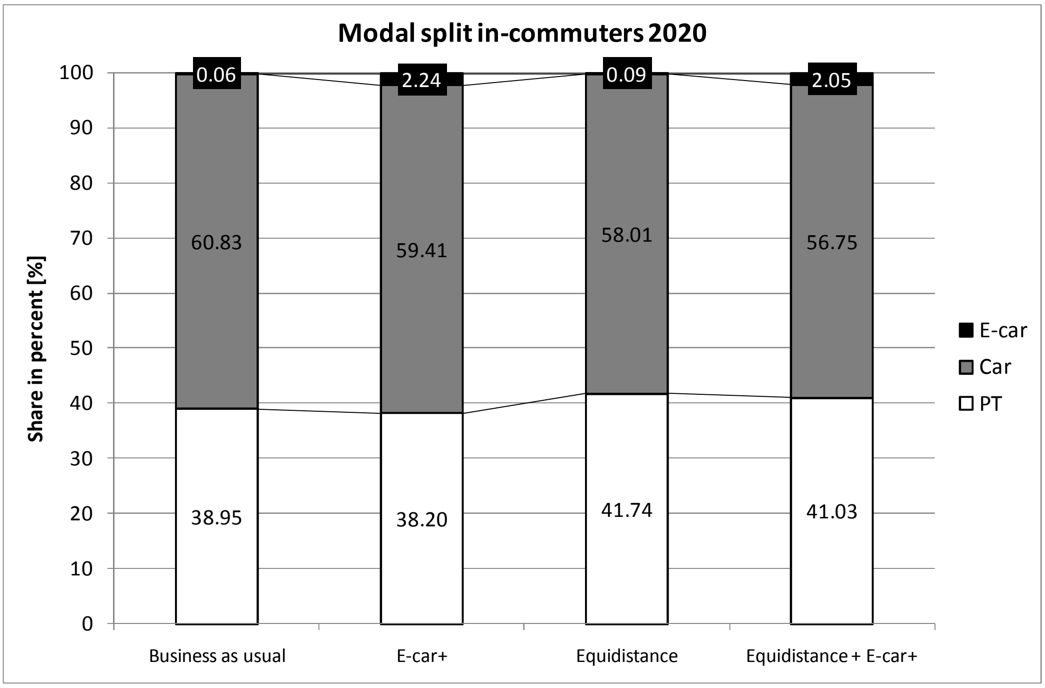

Figure 7 - Modal spit in-commuters 2020 - comparison of all scenarios

Until 2030 the use of e-cars increases significantly in both e-car promoting scenarios (E-car+ and Equidistance + E-Car+; see Figure 8). In none of the scenarios the objectives of the transport masterplan of Vienna can be reached (45 % PT use – 55 % PMT use). These results point out that further policy measures at the origin of the trip are necessary in order to fulfill this goal.

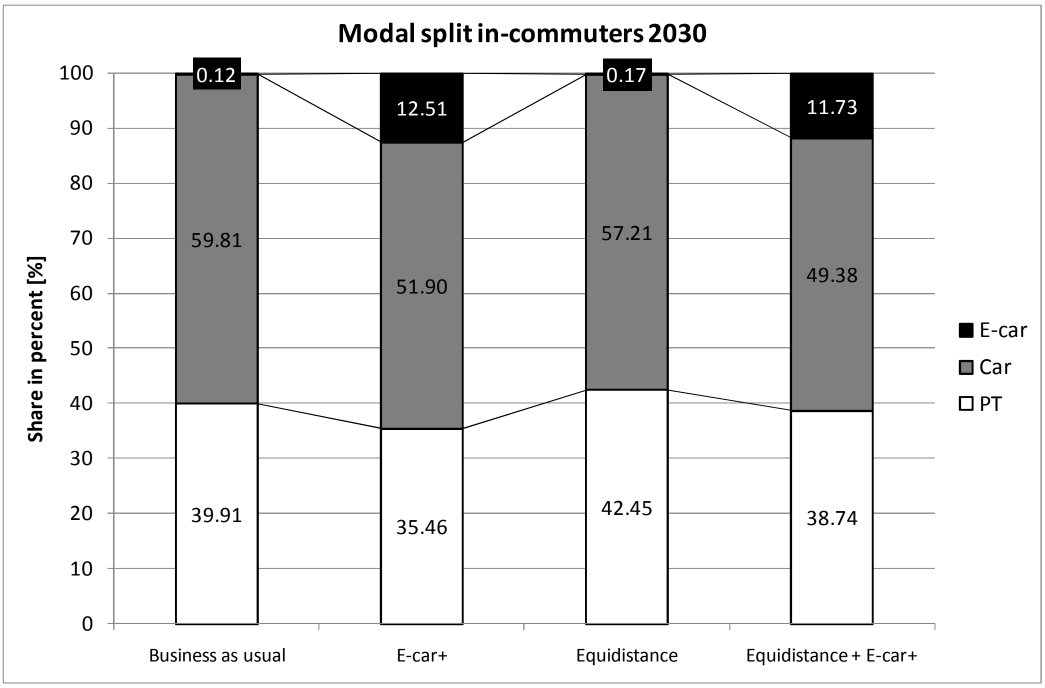

Figure 8 - Modal split in-commuters 2030 - comparison of all scenarios

In Table 6 the change in vehicle kilometers for the different scenarios compared to the BAU scenario can be seen. Following the pattern in the modal split change, the reduction of the vehicle kilometers is largest in the Equidistance + E-Car+ scenario.

Table 6 – Change in vehicle kilometers compared to BAUS scenario

Reduction of vehicle kilometers of cars in the years 2020 and 2030 in relation to the BAU scenario [%]				
		E-car+	**Equidistance**	**Equidistance + E-car+**
Vienna	2020	-2.1	-29.3	-30.4
	2030	-11.9	-28.7	-36.7
in-commuters	2020	-1.7	-6.6	-8.2
	2030	-10.0	-5.8	-17.1

7.2. Impacts on CO_2 - emissions

Figure 9 shows the development of CO_2-emissions for our four described scenarios. The most effective scenario in terms of CO_2 reduction is the combination of the promotion of e-mobility with the application of the principle of equidistance.

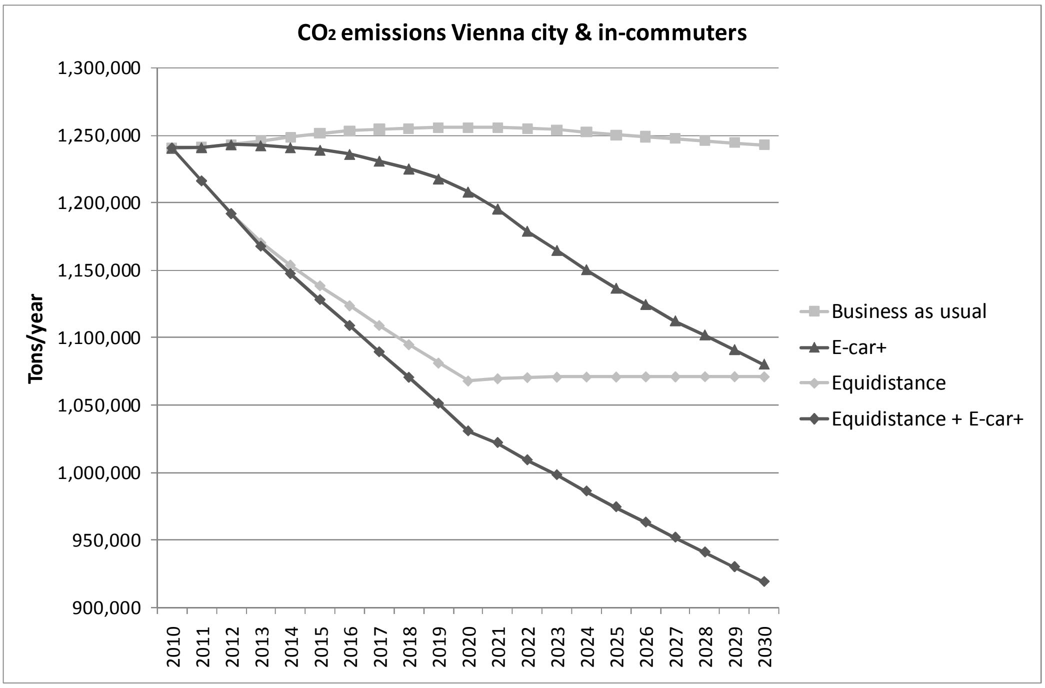

Figure 9 – Development of CO_2 emissions for all scenarios

7.3. Local emissions

Table 7 shows the reductions in NO_x emissions and PM in the year 2030 compared to the BAU scenario. As can bee seen the most effective scenario in terms of reducing these emissions is the Equidistance +E-Car+ scenario. In Vienna more than half of the primary emissions can be reduced in this scenario.

Table 7 – NO_x and PM emissions in the year 2030 compared to the BAU scenario

Reduction of NO_x and PM emissions in the year 2030 in relation to the BAU scenario [in %]			
	E-car+	**Equidistance**	**Equidistance + E-car+**
NO_x Vienna	-34.9	-30.9	-53.9
NO_x in-commuters	-33.4	-7.8	-38.9
PM Vienna	-36.7	-31.1	-55.2
PM in-commuters	-35.8	-8.1	-41.2

7.4. Impact on ridership in public transport

Whereas the ridership in public transport increases in the Equidistance scenario in Vienna as well as in its hinterland the percentage decreases in the hinterland in the scenario Equidistance + E-car+ (see Figure 10). The massive one-way advancement of e-cars (near parking places and charging stations) has negative effects on the transport policy goals and takes effect especially in the car-oriented suburban areas of the city. The promotion of car-traffic and infrastructure for cars decreases the ridership in public transport.

In the city of Vienna these negative effects can be diminished because of the parking organization based on the principle of equidistance.

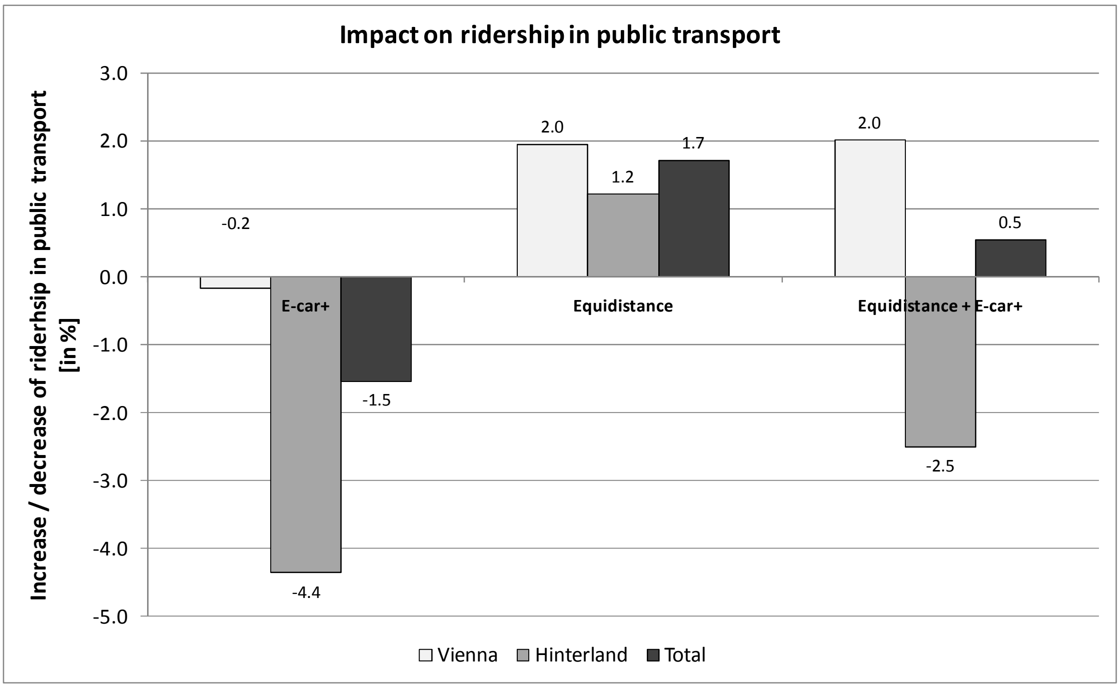

Figure 10 - ridership changes for the three policy scenarios

CONCLUSION

We show in this paper that the one-way promotion of e-cars contradicts the transport policy goals of the city of Vienna. The results can be applied for other cities which plan to organize traffic in a more efficient and sustainable way. One of the key measures to strengthen the modal split of non-motorized traffic and public transport lies in the parking organization. As soon as car drivers have to park their cars in collective parking garages a more equitable choice of means of transport is possible. The principle of equidistance and collective garages fits perfectly into the requirements for a livable city structure. E-cars are able to support these needs as far as the charging infrastructure is allocated in central parking garages and not in public space. Structures which permit short access and egress times to the car, promote PMT. Some negative effects of fossil fuel powered cars, like carbon dioxide emissions, can be reduced by e-cars. The problems of congestion, use of space, energy consumption and accidents can not be solved by e-cars. In order to benefit from e-cars without counterproductive effects, an implementation of charging infrastructure under consideration of the principle of equidistance is necessary.

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