ENERGY DEMAND AND CHARGING STRATEGIES OF BATTERY ELECTRIC VEHICLES

Leitinger C[1], Schuster A[1], Brauner G[1]

[1]Vienna University of Technology, Institute of Power Systems and Energy Economics, Vienna, 1040 Austria – leitinger@ea.tuwien.ac.at

Abstract
This paper is dedicated to examine the energy supply side of electric vehicles for passenger transport referred to the Austrian situation. Beside the resources, which are necessary as propulsion energy in certain scenarios, the CO2-Emissions of different kinds of electricity production are shown. Furthermore the process of battery charging is taken into account focusing on strategies for charging the batteries in a power grid friendly way.

Introduction
The conventional drive system using internal combustion engines causes in field of transport many problems. The well known topics are environmental pollution, climate effects and the lack of security of supply of fossil fuels in the long term. Because of that new strategies have to be found for a sustainable future. In recent years electric drive systems or partly electric drive systems in the way of hybrid electric vehicles got more and more attractive again offering solutions to some of the mentioned questions. Up to now there are also big challenges in the field of electric mobility. For instance the energy storage on board does not fulfill all needs of customers so far, especially costs and range. Also the electricity supply for electric mobility was not considered sufficiently in the past. Electric drives will be the future in mobility to some extent, therefore the challenges have to be solved the earlier the better.

Materials and Methods
Analysis on the energy consumption is done by using the physical laws for propulsion of vehicles. Research of literature gives information on newsworthy emissions of electric power plants as well as data of the transport sector.
In field of charging strategies a stochastic model of a certain amount of vehicles is built to create a synthetic profile of the power demand in distribution grids during battery charging. This is of relevance to discuss the effect on electrical power systems.

Results and Discussion
The consumption of vehicles is related to the sum of energy needed to overcome the rolling resistance and aerodynamic resistance. Considering further losses of the system, the energy consumption of a small or compact car aggregates to around 15 to 20 kWh/100 km.
In comparison, an average consumption of conventional cars of 7 l/100 km corresponds to around 60 kWh/100 km.
For comparison of the CO2-Emissions following table is taken into account.

Source for electricity production	CO2-Emissions
EU-Mix	650 g CO2 / kWh
Austrian Electricity Mix	440 g CO2 / kWh
Photovoltaic	100 g CO2 / kWh
Hydro Power	40 g CO2 / kWh
Wind Power	20 g CO2 / kWh

Table1: CO2-Emissions of electricity for different primary sources [1.]

As shown in Figure 1, electric mobility has least CO2-Emissions, when electricity is generated from renewable; especially wind power (4g/100km). But even if electricity is produced by a mixture of nuclear, coal, gas, hydro power (according to EU-Mix or even the better Austrian Electricity Mix), the emissions are less than for a conventional car with a consumption of 7 l/100 km.

By replacing one million conventional cars by electric cars on the streets with a mileage of 10.000 km/year, the CO2-Emissions could be reduced at least by 0.44 Mio tons CO2, if electricity is produced by the Austrian Electricity Mix, or even by 1.24 Mio tons CO2, if electricity is generated by an renewable energy mix (40 g CO2/kWh). Moreover, one million electric cars would consume just 2 TWh per year, in relation to the total electricity demand of around 70 TWh per year for all energy services in Austria in total.

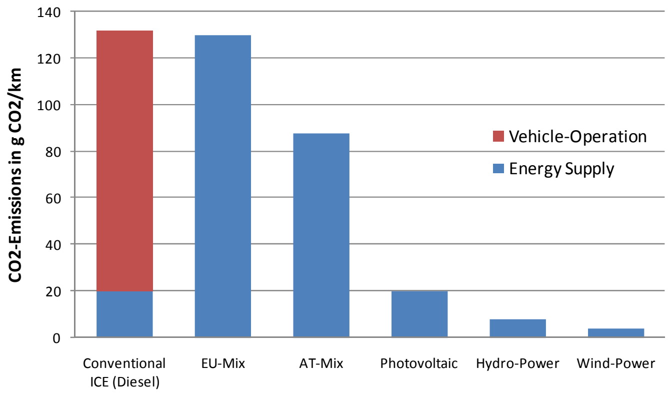

Figure 1: Comparison of CO2-Emissions of conventional and electric cars

Energy demand is a time invariant specific value for a certain milage per year. For investigations of the load in local power grids, the real-time values of the power demand for simultaneously charging of an aggregation of electric vehicles are important.
In general there are four potential strategies for daily charging of vehicles, as shown in figure 2:

- Immediate end of travel day
- Delay to 10 p.m.
- Optimized to off-peak times
- Multiple charging events per day

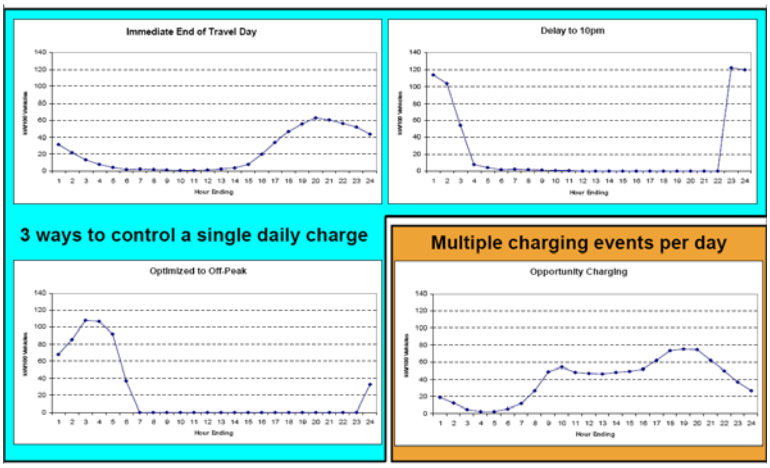

Figure 2: Potential strategies for daily charging of electric vehicles [2.]

Analysis is made for the worst (No.1) and best (No.3) strategy in a local area power grid including an amount of 100 households and a simplified set of transport statistics. Charging immediately at end of travel day, the power demand peak during the evening hours would rise by one third of the households' profile. Charging during off peak times the power demand rises just to half of the peak value during nights, as shown in figure 3. This shows the importance of well sophisticated and controlled charging intervals to avoid further peak loads in power grids by integration of electric mobility as electric energy service.

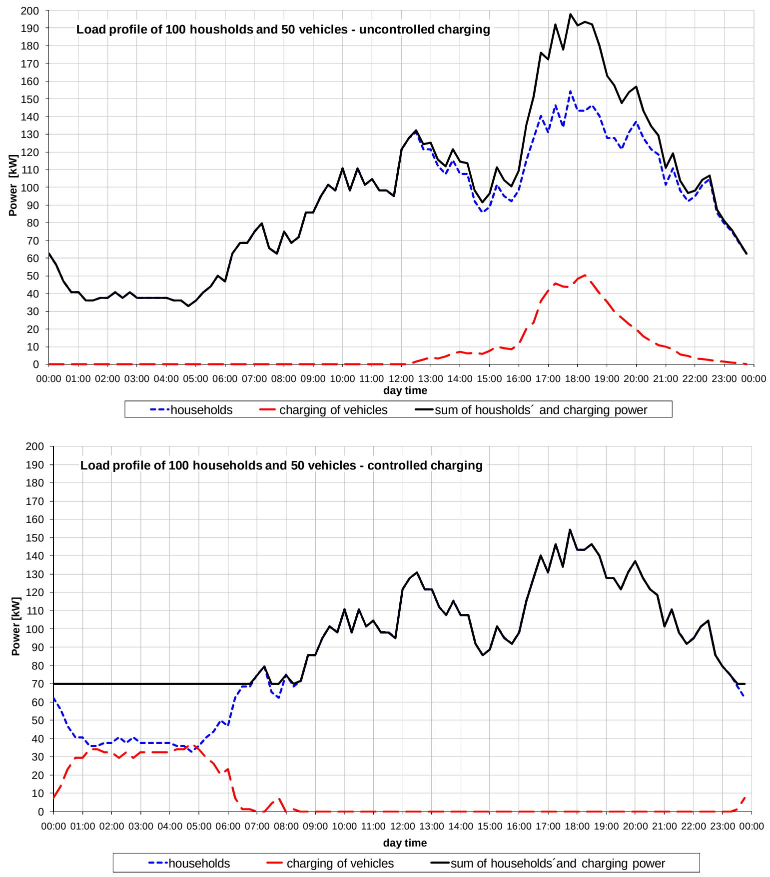

Figure 3: Load profile of households and vehicles for strategy No.1 and No.3 [Leitinger, Schuster]

Further research will be done on specifying the transport statistics reaching higher accuracy. Especially strategy 4 (multiple charging events per day) gets big importance, when cars are plugged to the grid as often as possible and when fluctuating renewable energy should be balanced by charging the vehicles´ batteries.

Conclusion

- To reach certain emission reduction goals in transport, future vehicles have to be driven by electricity produced by renewable energies. This can save up to 1.24 Mio tons of CO_2 per million cars.
- In respect to the integration of electric mobility into power grids as a new electric energy service, it is necessary to consider daily charging cycles of the batteries very carefully.

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