The rocky road to electric transport

Electricity-powered vehicles will play an important part in road transportation in the future. But it will be a while until new concepts like plug-in-hybrid vehicles gain acceptance over conventional combustion engines.
Electric vehicles have two attractive qualities: they are environment-friendly—at least as long as they are powered with electricity generated from renewable sources—and energy-efficient. Electric vehicles also have serious disadvantages: their current range is still very limited, their batteries are heavy, their manufacture is highly energy-intensive, and most of all they are expensive. It is exactly for these reasons that electric vehicles have until now not been able to establish themselves in the marketplace. “When certain car companies claim that in a few years we’ll be traveling around in electric vehicles on a massive scale, that’s just an advertising gimmick,” says Konstantinos Boulouchos, head of the Aerothermochemistry and Combustion Systems Laboratory (LAV). Still, he is convinced that in the foreseeable future, partially electrically-powered vehicles will be an everyday sight on our streets. “The road to an electric automobile future is long and difficult, but we’re on the right track. It’s a robust path that we’re able to go along step by step.”

**Increasing electrification**

This path consists of increasing the degree of electrification of individual autos bit by bit. A first step is hybrid vehicles, which are already being produced today as a standard procedure. The next step is the so-called plug-in hybrid vehicles, which have larger batteries and draw a portion of their energy from the grid. Boulouchos estimates that the range of such vehicles with charged batteries will already reach 50 kilometers within five to seven years. They will however remain expensive. “Combustion engines will play a dominant role in road transportation in the future.” In any case, an overly fast electrification is not sensible, since not enough energy from renewable sources is available to power all autos with electricity. “On the supply side as well, a continuous development over decades is required; otherwise, the reconfiguration of the transportation system doesn’t make sense.” The electric companies are looking into how the electrification of road transport would affect them. Thus, Zurich Municipal Electric Company supports the ARTEMIS project, which is closely examining the situation in the city of Zurich.

Three partners from ETH are involved in the project: Kay Axhausen’s group from the Institute for Transport Planning and Systems is simulating traffic flow in the city of Zurich in detail with the help of agent-based models. Boulouchos’ group at LAV on the other hand is estimating what the future fleet may look like and how much energy the various vehicles will consume on their trips. This will allow a calculation of the overall energy requirement. Finally, Göran Andersson’s group at the Institute of Electrical Power Transmission and High Voltage Technology is working on the network side of the system; that is, they are clarifying how the demand for electrically-powered transportation would impact electricity demand, its transmission and distribution, and how this demand would change when electricity prices rise with increasing power demand. “We’re pursuing an entirely new approach with this project that takes a comprehensive view of the problem”, explains Fabrizio Noembrini, leader of the research at LAV.

**Which technologies are the most effective?**

Within the framework of the EU’s TOSCA project, whose kickoff meeting took place in September, the LAV is exploring the consequences of an increasing electrification of road transportation on a general level. “Our group is concerned with private vehicles, trucks, buses, as well as ships,” explains Noembrini. “The point is to identify reduction potentials for controlling CO2 emissions and to determine the corresponding cost curves. Then we can pinpoint which technologies yield which CO2 reductions and what their associated costs are.”
Why plug-in hybrid electric vehicles will dominate the passenger vehicle market

Thomas F. Rutherford

Transportation has gained increasing prominence in the climate policy debate, as there is increasing interest in prospective new vehicles and the scope for reduction in carbon emissions through improved efficiency and the potential role for electric vehicles.

Research within the framework of the MERGE integrated assessment model shows that in virtually any baseline scenario for the US, plug-in hybrid electric vehicles (PHEV) dominate conventional internal combustion vehicles in the passenger vehicle market. This happens for several reasons: liquid fuel prices rise faster than electricity price, capital cost premium for PHEV falls, and the use of PHEV is constrained only by introduction rate. Electric vehicles are highly efficient, requiring less than 1 GJ per km as compared with 3 GJ or more per km for conventional vehicles. These developments, while positive, have a limited impact on greenhouse gas emissions. Electricity requirements for passenger vehicles in any scenario amount to less than a 6% increase in aggregate generation. Passenger vehicles emit but a small fraction of global carbon emissions.

Integration of plug-in hybrid vehicles in a secure electric power supply

Matthias Galus, Göran Andersson

Providing a secure and sustainable power supply for plug-in hybrid electric vehicles (PHEV) poses a challenge for the intelligent electricity grid of the future. The PHEV moves between the poles of balance group concepts and the requirement to make better use of energy from renewable sources and, on demand, to feed this energy back into the grid. The ETH polyproject Artemis (see the main text) explores this question using a holistic approach. It links grid, vehicle, and transportation simulations. Agent-based transport simulations (MATSim) are used as an input value for an electric grid. The optimization of this grid guarantees that transformers and cables are not overloaded and that local voltage problems in the low-voltage grid are avoided. The tool also allows simulation of an energy recovery system on the basis of control signals from the grid (emergency service). This enables researchers to examine the feedback of the vehicles on the grid. Signals about critical grid conditions are passed to MATSim for a new system condition, which alters the behavior of agents. Primary energy as well as the energy consumption of individual autos and the future fleet dynamic are also integrated.

» http://tinyurl.com/powersyslab
Formula Hybrid – Racing to the Future!

Ismail Abou-Zeid, Lina Graber, Konrad Hertig, Vasco Lenzi, Dani Wagner, Koni Wepfer

22 BSc students of mechanical and electrical engineering at ETH Zurich and Lucern University comprised the team that built a hybrid car for last year’s race of the “Formula Student/Hybrid” competition. In the car’s development, emphasis was placed on the efficiency of the power train.

After a year of construction, finalizing, and optimizing, the result stands on its own four wheels: the hybrid sportster Pegasus. Equipped with a 95 kW-strong electric motor (EM) and a 30 kW combustion motor (ICE) in parallel, Pegasus offers high performance at low fuel consumption. In about 4 seconds, this speedy car accelerates from 0 to 100 km/h. In the endurance race over 50 km, it used 0.53 liters of fuel and 4 kWh of electrical energy. This all-around performance is provided by the parallel power train developed by the team. The electric motor sits directly on the main drive shaft and transmits its momentum to the wheels by a differential. The ICE is located on the supplementary drive shaft, which is connected to the main drive shaft with a gear belt. According to need and operating conditions, the ICE can be engaged to deliver power. It is restricted to operating under full load, since its efficiency is highest there. If this provides greater momentum than required, the additional power is fed into the batteries through the electric motor, analogous to the brake energy.

Compared to industrial concepts, this hybrid drive train combines parallel and serial concepts. This way, the advantages of both systems can be capitalized on. To achieve the highest possible efficiency, the structure is oriented around a parallel concept, while the task allocation (control) follows the series concept; that is, the EM covers the peaks, while the ICE increases the range of the vehicle.

Further information is available at:

» www.formula-hybrid.ethz.ch