There's still a long road ahead before electric cars like the eRuf Stormster (below) can recharge on wind-generated electricity. Siemens and Danish company Lithium Balance are helping the vision become a reality (right).

All Charged Up

Major cooperative projects are paving the way for the launch of electric vehicles. Experts from industry and universities are creating the technological basis for linking vehicles to the power grid. In fact, field tests are now under way, especially in Denmark and Germany. One key objective is to use electric cars as energy storage units that can compensate for fluctuations in wind power.

As recently as five years ago, the idea that hundreds of thousands of electric cars could be on the road in Europe by 2020 was considered a futuristic scenario. Hardly anyone believed that the idea of driving with electricity could be implemented so quickly, and on such a grand scale. Times have changed, however, and work on readying electric cars for everyday use is proceeding at full speed. At the same time, some components of their energy source — the power grid — are being completely redefined (see *Pictures of the Future,* Fall 2009, p. 44). Two European regions in particular are leading the way to the future of electric mobility — Denmark and Germany's Harz region in the country's middle. Both already obtain a large portion of their electricity from renewable sources, especially wind. In Denmark, the figure is 20 percent; in the Harz, wind, biogas and solar facilities cover 50 percent of energy needs. As a result, both regions often face the same problem: too much wind energy.

When strong wind causes turbines to really get moving, they can actually meet more than 100 percent of each region's electricity demand. To prevent the grid from overloading, wind facilities in Harz are shut down — much to the annoyance of their operators. Danish energy suppliers, however, are legally required to use the excess wind power, which they pass on to their European neighbors. What's more, they have to pay transmission fees for the privilege. And the problem could get worse, since the share of electricity generated by wind power is increasing in both the Harz and Denmark. The latter hopes to have around 50 percent of its average electricity demand covered by wind by 2025.

Electric vehicles could help solve the problem by acting as a virtual surplus electricity storage system. Specifically, thousands of electric cars would recharge their batteries when winds are strong, primarily at night. Conversely, during periods of calm, they could resupply the grid at higher prices. It's a great idea — but can it work? For example, how can electric cars and the power grid communicate reliably? How can vehicles be recharged quickly and safely? And how is everyone to be billed? Two major cooperative projects in Denmark and the Harz are seeking answers to these questions with the help of Siemens experts.

One project is headquartered at the Risø research center at the Technical University of Denmark (DTU), not far from the famous Viking Ship Museum in Roskilde. The center houses wind turbines, solar photovoltaic systems, a transformer station, and a vanadium-ion liquid battery the size of a shipping container. Here, the energy consumers are electric heating units in the center's office buildings, hybrid cars, and several small batteries that simulate additional vehicles. The research center thus has a miniature power grid that can be used to test the interaction between various components.

Risø is home to Denmark's EDISON ("Electrical vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks) project, the world's first major effort for bringing a pool of vehicles to power outlets. Practical testing will begin in 2011 on the island of Bornholm. "We're focusing mostly on the question of how electric vehicles can be charged quickly, safely, and efficiently," says Sven Holthusen, who is responsible for the EDISON project at Siemens' Energy Sector. Holthusen and his colleagues analyze, for example, how a vehicle can be recharged at different types of charging stations or how a large number of batteries can be recharged simultaneously.

Holthusen knows that electric cars will become truly attractive to consumers only when they can travel long distances and be recharged within a few minutes. Electric cars these days are normally charged at an 11 kilowatt (kW) outlet. A typical battery with a 25-kilowatt-hour (kWh) storage capacity thus takes more than two hours to fully recharge. Increasing the charging power would lower the charging time. That's why Holthusen's team of researchers is developing 120 kW technology, which reduces the charging time to just a few minutes. However, with charging currents of up to 300 amperes and 400 volts of alternating current (a.c.), the load is equivalent to powering nearly 20 households.

"Heat generation during recharging with a.c. is one of the biggest challenges at the moment," explains Holthusen, who is testing charge controllers that would be installed in vehicles as well as those that would be part of charging stations. Onboard controllers offer the benefit of not having to be integrated into the power pump, which reduces infrastructure costs. Such controllers also ensure that each vehicle optimally controls the charging process in line with its battery's requirements. External controllers, on the other hand, are better at dissipating heat, thus enabling higher charging currents.

Siemens researchers are working on a 120 kW system for recharging electric vehicles in just a few minutes.

No one knows which charging technology will gain the upper hand. That's why Siemens is developing different technologies in parallel in its Inside Car and Outside Car electric mobility teams. The teams develop and test components for vehicles and grid technologies. Holthusen is also looking at direct current (DC), since it allows batteries to be charged without a controller. "However, DC is more dangerous, mainly because of the arcing that occurs in the event of a short circuit. Commonly used AC fuses cannot be used for protection in such a situation." Holthusen is thus working on new, safe approaches for DC supply.

Along with the DTU and Siemens, EDISON project partners include IBM, which is developing the software infrastructure for linking decentralized components, the Eurisco development firm, and energy suppliers Dong Energy and Østkraft. The latter are mainly interested in practical solutions for feeding wind power into the net; Østkraft is also organizing a field test on Bornholm. With wind energy continuing to expand worldwide, Holthusen and his colleagues believe all the technologies they're working on have good chances of market success. In the Outside Car area alone, they estimate that global demand for electronic components capable of expanding the power grid and charging infrastructure will total over ten billion euros by 2020.

The German government is funding the expansion of electric mobility in eight regions. In Munich, Siemens is participating in a pilot project with BMW and the local municipal utility (SWM). Here, BMW plans to expand its trial fleet of "Mini-E" electric vehicles to at least 40, Siemens is providing technology for the next-generation charging infrastructure — including fast charging — and SWM is supplying "green" electricity. Siemens has also launched a project in Berlin in which electric vehicles are being used on a daily basis as company cars. The project includes six electric smart models provided by Daimler, which can "fill up" at 20 charging stations at the main Siemens locations in Berlin. Siemens has its own medium and low-voltage network here, which can charge or discharge the cars.

Fast Charging. The Harz.EE-Mobility project has 15 partners. They include several research institutes and universities, public utilities, pow-

er grid operator E.ON Avacon, Deutsche Bahn, Siemens, and mobile radio company Vodafone. Together, these partners are paving the way for future electric mobility in the Harz region. The project seeks to identify ways of making recharging convenient, intelligent, and reliable. The partners have already installed the first power pumps not only in the Harz but also in Copenhagen, Denmark, where vehicles from the EDISON project also recharge. EDISON and Harz.EE-Mobility thus complement one another and share results. Whereas the EDISON partners focus mainly on power electronics and fast charging technology, the Harz project is concentrating on the charging process and vehicle-grid communication.

"The most important thing for users is that charging should be fast and simple," says Dr. Jörg Heuer, who is responsible for the Harz project at Siemens Corporate Technology. Achieving this goal will require automatic communication between the vehicle and power pump. Europe now has a standardized connector that includes not only a charging cable capable of handling up to 44 kW but also a data-exchange channel. The power pump uses a communication protocol to determine when a vehicle is ready for charging. Conversely, the pump tells the vehicle how much charging power it can provide.

An additional communication channel for automated payment or the transfer of other vehicle data can also be activated. "If a large number of vehicles recharge simultaneously in a parking garage, we could have a local overload," says Heuer. "That's why vehicles need to be able to communicate and coordinate their requirements." Siemens is therefore working with many companies — including RWE, EDF, Better Place, BMW, Daimler, Renault, Toyota, Honda, and Ford — on international ISO/IEC standardization of a communication protocol. Such a protocol would make it possible for power pumps and vehicles from all automakers to exchange data via the pump's cable or a wireless link. The protocol is to include a system for multi-stage vehicle authentication, which would prevent misuse and electricity theft. Heuer also serves as a consultant in various standardization bodies.

Without coordination, the simultaneous recharging of many vehicles could overload local grids.

Vodafone is involved in the Harz.EE-Mobility project because charging at various stations resembles cell phone roaming between different wireless providers. Given that the future billing process might therefore be similar, Vodafone is contributing its experience with movement profiles. After all, it's relatively easy to find out where a cell phone is and where it goes when it's on. "In our project, we want to study the extent to which movement profiles of electric vehicles can reveal information about potential demand for electricity at places like park-and-ride lots or parking garages," says Heuer. "The grid needs to be capable of reacting should demand rapidly increase at any of these locations." In 2010, some 30 Audi A2 models retrofitted as electric vehicles will hit the road in Harz and surrounding regions and cities that are also participating in the project. Project staff will use the cars to act out various scenarios. For example, they will simulate peak demand during simultaneous charging at the Magdeburg railway station parking garage. Deutsche Bahn, which operates car-sharing fleets, is very interested in the results.

Intelligent Grid. "When you include all the wind turbines, biogas and solar energy facilities, small power plants, and cars, our project will link around 2,000 electrical units," says Heuer. "There's never been a project that big before." With the help of communication solutions that align supply and demand, it may even be possible to increase the share of eco-friendly electricity involved to more than 50-percent by adding locally-produced energy from renewable sources. That energy would then no longer have to be exported. "With such a large number of electricity producers and consumers involved, it isn't practical to establish an overriding control center like the traditional ones used in centralized networks and major power plants," says Heuer. In other words, nothing will work without intelligent communication technologies and predictive algorithms. Researchers are particularly interested in how the grid will behave when electric cars link up and disconnect. To this end, project staff are developing mathematical rules that use the principles of probability theory to predict when, where, and how many vehicles will require electricity.

To make recharging easier, the project consortium includes experts in user-friendliness. "Drivers will have to choose between a maximum of only three or four charging modes," Heuer says. In fact, two modes — "Charge at Maximum Speed" and "Charge at Minimum Cost" — might be all that's necessary. Use of the charge pump will be automatically billed via cell phone. Harz.EE-Mobility will reach cruising speed in 2011. That's when the last of the test's electric cars will hit the road to demonstrate that recharging is as easy as filling up today. ■ *Tim Schröder*

At the Risø research center, scientists from the Technical University of Denmark and Siemens are testing how electric cars, power grids, and renewable energy generation systems can operate in harmony.