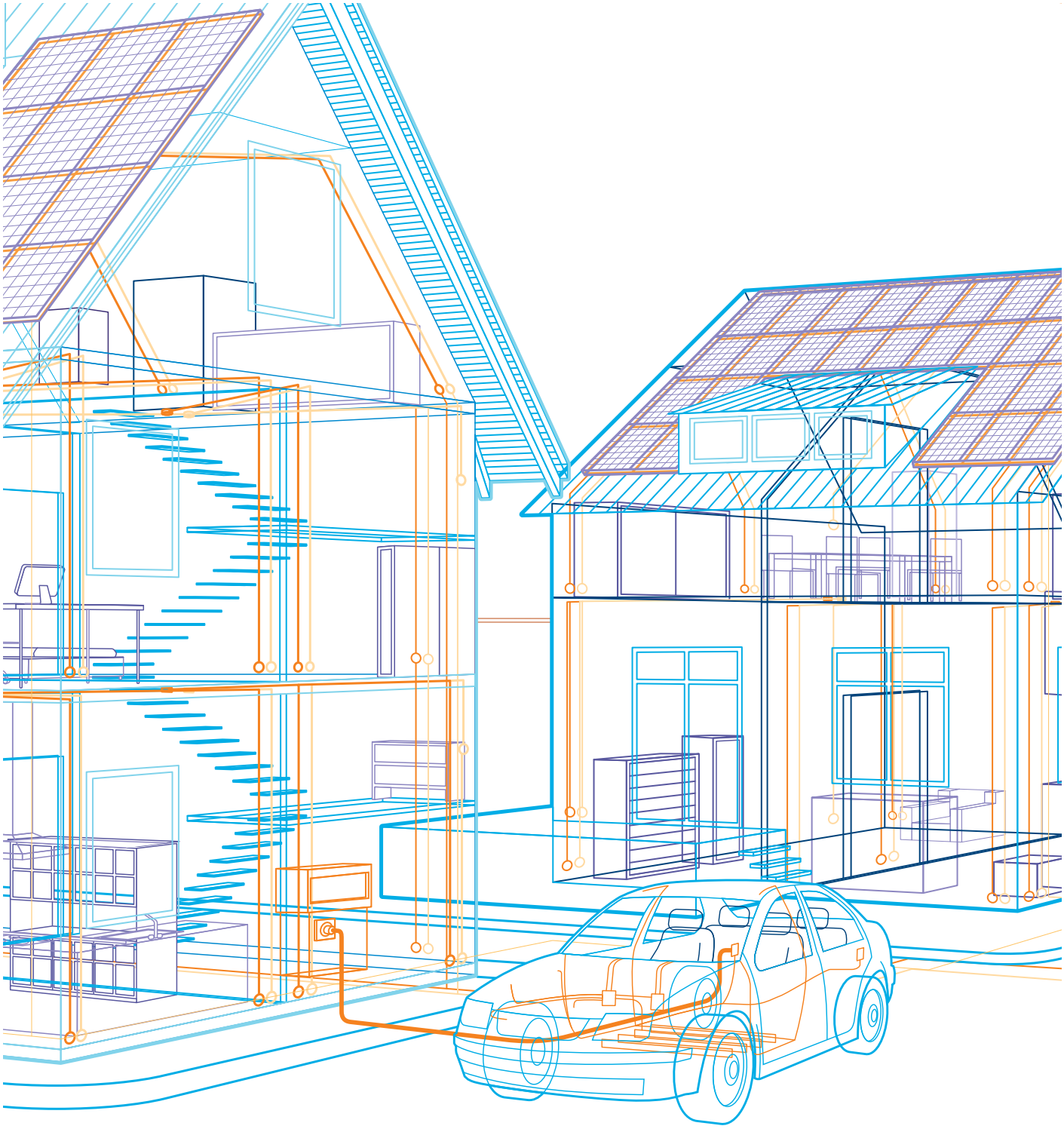
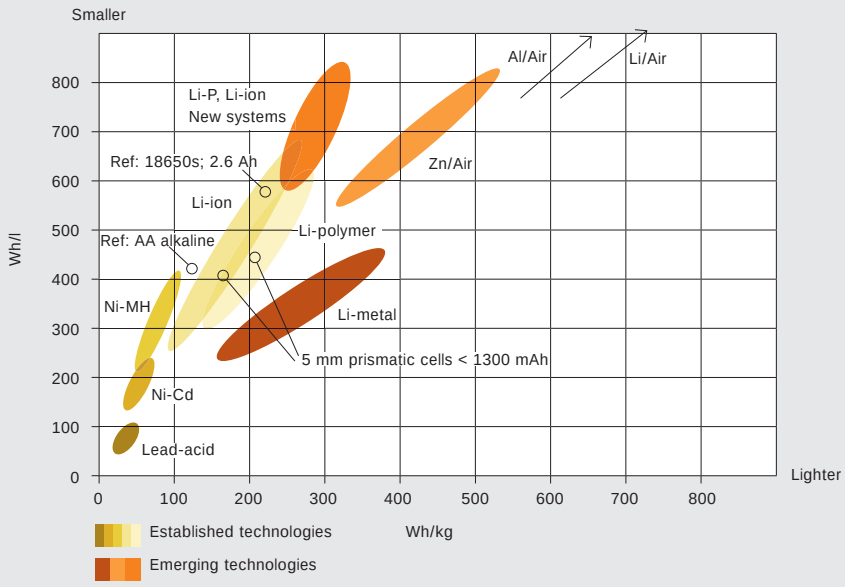


Dawn of a new age

ABB’s electric vehicle charging units and smart grid technologies are supporting the vision of a new era of transportation

NICK BUTCHER, SIMON FELSENSTEIN, SARAH STOETER, CÉCILE FÉLON – Refilling the tank now has new meaning at ABB. As part of its commitment to building a smarter grid, the company has extended its reach into a relatively new market, one that is discretely popping up in the parking lots of larger cities – electric vehicle charging. As more governments are pushing emissions legislation and offering incentives for electric car buyers, the demand for fully electric vehicles continues to grow, encouraging many carmakers to also expand into this new market. With this in mind, ABB is developing electric vehicle charging systems that foster a new vision of transportation.

1 Battery technologies



Although it would seem that electric cars have only recently made their way into the market, they have actually been around for almost 200 years. While the first electric cars were developed in the 1830s, it wasn't until the end of the century that such vehicles began to receive greater attention. Although there were also cars powered by steam and by internal combustion engines (ie, gasoline powered), electric cars had the advantage of being quieter, smoother (ie, little vibration) and less odorous than their competitors. In addition, gasoline powered cars not only required hand cranking to start but the gears were also extremely difficult to shift, and steam powered cars required very long startup times. Until about the 1920s, electric cars were quite successful.

But circumstances were changing. In the United States, for example, road systems were improving and as a result cities were being connected – this brought about the need for cars that could travel longer distances. In addition, crude oil was discovered in Texas, driving down the price of gasoline, and an electric starter was developed, which replaced the laborious hand crank. And mass production of cars with internal combustion engines made such cars more readily available and affordable than their electric counterparts.

Until the 1960s, the focus of the automobile industry was on cars with internal combustion engines, and progress in electric vehicle (EV) technology was slow at best. But it soon became clear that dependency on gasoline powered cars was necessitating the dependency on foreign crude oil, and the resulting emissions were demanding the exploration of alternative fuels. And so interest in electric cars picked up, and numerous electric car models were developed over the years. One of the more famous electric cars of this time is the Lunar rover, which in 1971 was the first manned vehicle to be driven on the moon.

Dawn of the electric age

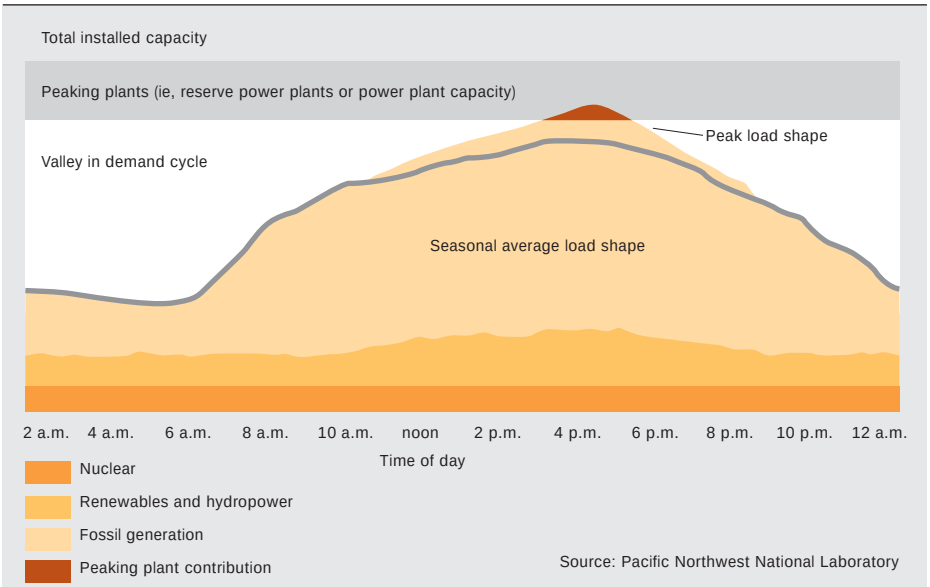
The debate continues as to whether the age of electric transport is truly here, or if this is simply another cycle of boom and bust. The skeptics' views are not without foundation – electric cars have suffered several such cycles in the past. The limitations of battery technology – still today the critical issue in electric vehicle success – have played a leading role. It is through recent advances in battery technology that the dream of zero-emissions mobility may finally be within reach for the mass market.

The first generation of electric cars used lead acid batteries. These were characterized by high weight and limited performance, powering only short-range vehicles, which were not attractive to the wider market. Lead acid batteries have made incremental improvements over the years, but the next generational leap in electric vehicles came with the nickel-metal hydride (NiMH) batteries in the 1990s. These saw dramatic improvements in range and performance, best personified in the highly capable GM EV1. Ultimately, however, the verdict from car manufacturers was that NiMH batteries, while much better than lead acid, were still not sufficient to meet market needs for fully electric vehicles in terms of price and lifetime.

Within the last 10 years, a new rechargeable battery has been developed, driven by tremendous volume in the consumer electronics market. This battery, based

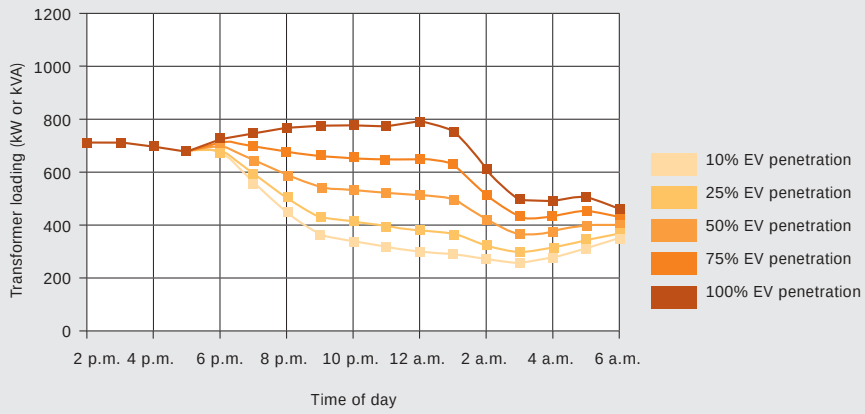
Through recent advances in batteries, the dream of zero-emissions mobility may finally be within reach for the mass market.

2 Demand cycle of the US electricity grid



Source: Pacific Northwest National Laboratory

3 Loading of a transformer with smart charging



Blending rail and road

The Urban Commuter (UC?), a lightweight two-seater electric city car developed by Rinspeed*, a Switzerland-based company, was showcased at the 2010 Geneva motor show. This fully electric car measures less than 2.6 m in length and is equipped with a permanent 3G network connection. The small electric power plant is not only designed to help prevent congestion in city centers, but it can also be easily loaded onto custom-built train carriages for long-distance trips and integrated into the train's charging grid. The driver can take advantage of the train's facilities or the vehicle's technological features such as video chat, IP telephone calls and e-mail while in transit. At the destination, the car is fully recharged and ready to go.

This visionary project not only develops the idea of the electric vehicle, but also of sustainable mobility that includes privately owned cars and public transportation. ABB can help make this possible.

* See www.rinspeed.com

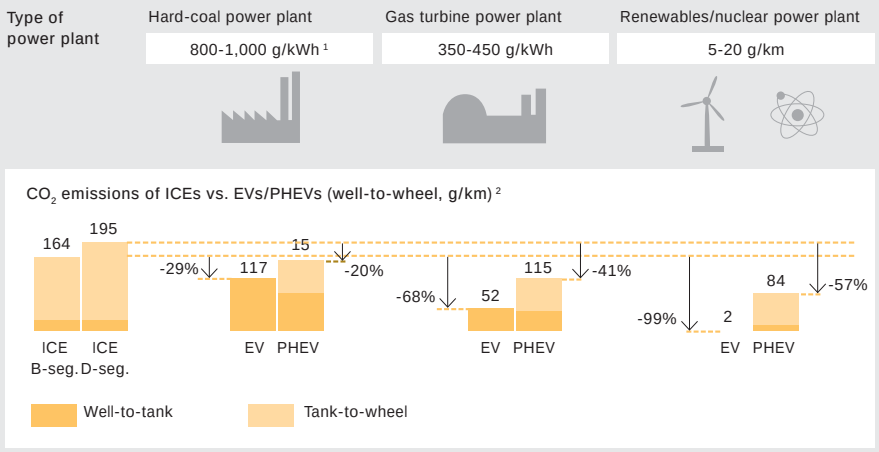
on variants of lithium-ion chemistry, delivers yet another giant leap ahead from what was achieved with NiMH. While lithium-ion batteries today still store much less energy per kilogram than oil – and are much more expensive than a tank of fuel – the extremely high efficiency of electric vehicle drivetrains and the low cost of electric energy per vehicle-kilometer mean that electric cars are finally in a position to go head-to-head with internal combustion rivals. Further major battery innovations are in the pipeline, many offering commercial promise on a surprisingly short timeframe → 1. Combined with concerns regarding climate change and energy security it seems likely that the electric age has finally come to stay – a premise reinforced by the announcements of models coming to market within 2010 by several vehicle manufacturers. These announcements refer not to small production-run concepts, but to electric vehicles to be produced in volumes of 100,000+/annum within the next one to two years. In total more than 20 different models of plug-in electric vehicles are expected to enter the market by 2012.

As the Li-ion battery is the critical part of an electric car, fully-automated large-scale production of dedicated automotive batteries needs to be implemented to ramp up volume and bring down costs. ABB provides turnkey solutions including the robotics used in cell manufacturing; module and stack assembly; as well as the power electronics to run test cycles of charging and discharging at every stage of the manufacturing process.

Electricity as fuel

Today, approximately 55 percent of all oil produced worldwide is used by the

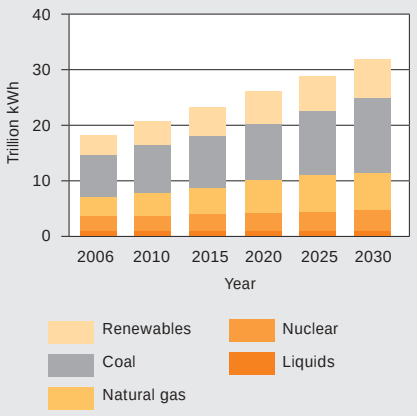
4 CO_2 emissions by power plant and vehicle type



1 EU hard-coal power plant installed today
2 Consumption of ICE B-segment vehicle: 5.9 l/100 km; ICE D-segment vehicle: 7 l/100 km; EV: 13 kWh/100 km; PHEV: 3.0 l and 8 kWh/100 km

Source: BMWI, World Nuclear Association, EU Commission, and Roland Berger

5 World electricity generation by source: business-as-usual predictions



Source: 2006 data source: Derived from EIA, International Energy Annual 2006 (June-December 2008), www.eia.doe.gov/iea. Projection data source: EIA, World Energy Projections Plus (2009).

transport sector, totaling almost 50 million barrels per day. One of the major perceived benefits of e-mobility is the creation of a transport system that is not dependent on oil as an energy source and has dramatically lower greenhouse gas emissions. With these goals come two critical questions: Where will the energy come from, and will the emissions be lower?

Challenge for the grid

In the case of electric vehicles, the answer to the first question is the electrical grid, though the grid is just a means of transmission, not generation. Energy is created in the wide range of power plants connected to the grid. For electricity to power cars, both the power stations and the electrical grid must have the capacity to transmit the electricity.

Generation management can be addressed by ensuring that car charging happens when energy is available, rather than randomly, which has the potential to create significant peak loads on the grid. With smart charging management, the existing power plants in many countries could provide energy for most of a vehicle fleet without any increase in nameplate capacity [1], primarily by using overnight capacity, which is presently underutilized. ➔ 2 shows the large valleys in the demand cycle in the US electricity grid where electric vehicles could be charged with no additional peak loading. The generation profile also highlights the potential issue regarding the electricity source; this is discussed in more detail in the next section.

Taking the grid into account is critical to avoid unnecessary costs. For a local distribution transformer, "dumb" charging (ie, charging any time of the day) could result in transformer overload and a local blackout even if only one house in 10 was using an electric vehicle. With smart charging, however, the transformer load can be managed within the limits even when every house in the neighborhood makes the switch away from oil ➔ 3.

Of course, every smart charging system needs to be integrated into the distribution management system and SCADA system to ensure interoperability and optimal benefit for both the grid and the electric cars. Today such grid management systems are to a large extent supplied by ABB.

> More than 20 different models of plug-in electric vehicles are expected to enter the market by 2012.

Emissions and renewables

Electric vehicles are seen as a solution for clean sustainable transportation. They have no tailpipe emissions at all – in fact they have no tailpipe. But to draw a fair comparison with the existing oil-fueled fleet it is necessary to look at the whole energy delivery system.

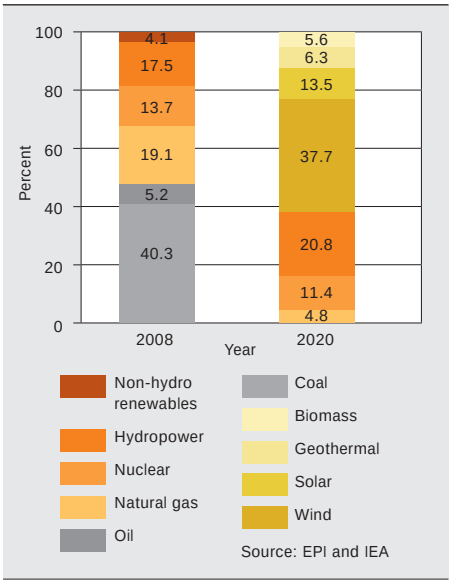
The effective emissions of an electric car depend to a large extent on the emissions of the energy source creating the electricity. Electric cars that draw their power from an old coal power plant are only marginally cleaner from a greenhouse-gas perspective than the oil powered cars they replace, and may in fact be worse from a life-cycle perspective, especially when compared with the latest generation of diesel engines. However, they do still have all the benefits of massively reduced local air pollution ➔ 4.

Thus, from a holistic perspective, a case is made for low-emissions electricity generation. Looking at new generation technologies, electric vehicles are already far superior to alternatives even with combined-cycle gas power plants, and when powered by truly low-emissions energy such as nuclear or renewable, they are almost completely greenhouse-gas-emission free.

The forecast presented in 2006 by the IEA will not derive the hoped-for benefits

Footnote
1 Nameplate capacity is the amount of energy that a generator is designed to produce.

6 World electricity generation by source: ultralow emissions possible



in reducing greenhouse gas emissions simply by switching to electric vehicles. To truly realize the benefits of electric transportation, a massive shift toward clean energy sources will be necessary ➔ 5. The economic and political feasibility of such a huge shift to clean energy remains to be seen, and it will take bold action to achieve targets as ambitious as those indicated in ➔ 6.

Particularly interesting is the potentially constructive interaction between electric vehicles and renewable generation such as wind and solar. By using smart grid technologies in combination with the storage reservoir (ie, the vehicle battery) to manage the supply and consumption of energy, the challenge of both electric vehicle and renewable energy integration could become much less daunting than either challenge considered in isolation.

The last mile – EV charging points

One of the often cited benefits of electric vehicles is that the cost associated with their infrastructure is much lower than, for example, hydrogen, because electricity is already widely available. While this is certainly a significant benefit, the reality is not quite so simple. The electricity still needs to be transferred from where it is (the grid) to where it is needed (the batteries onboard every electric vehicle). Furthermore, this must be done in a manner that is fast, convenient, simple, cost effective and safe. The solution, which ABB is working to provide, is the electric vehicle charging point. These units will be available in three primary types, depending on the application.

Residential charging

Home chargers deliver efficient, low-power vehicle charging that can refill a battery during the night, reaching full capacity before morning. Charging overnight ensures that the load on the grid is low, and the car is refilled economically using low-cost night-rate power. A range of home chargers are available to suit the needs of different homes – indoor, outdoor and wall mounted – and all incorporate the safety systems you can expect of any home appliance. ABB's portfolio contains everything that is needed to build safe and efficient home charging devices.

Public charging

Public chargers are semi-fast charging solutions that can charge a battery in a few hours while the driver is at work, or during everyday activities such as shopping or dining out. ABB products will be found in charging poles throughout the town or city at company parking lots, public buildings, stores and large parking garages.

These charging poles are built strong and safe to fit the requirements of a public space. In most cases the consumer will pay for the electricity used, so the charging pole will include an authentication and/or payment system.

> With smart charging management, the existing power plants in many countries could provide energy for most of a vehicle fleet without any increase in nameplate capacity.

Fast and ultrafast charging

Fast and ultrafast charging systems use high-power converters within the charger (rather than onboard the car) to rapidly charge the battery. Fast chargers compatible with existing batteries are already able to recharge 80 percent of the battery in less than 25 minutes. Future ultrafast chargers will allow a ”fuel stop” equivalent for EVs, charging the car in the shortest possible time. Combined with the latest battery technologies, this could allow a full recharge in less than five minutes. These chargers will be installed in highway rest areas and convenient city refueling points. Grid energy management and power quality are provided by state-of-the-art power electronics, smart grid interfacing and integrated energy storage to manage the variations in power production. ABB's direct-current fast-charging station concept was presented at the International Geneva Motor Show 2010, together with Protoscar's LAMPO^2 EV concept. This high-power charger is capable of refueling a more than 100 km range in only 10 minutes.

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