Electric Vehicles and Renewable Energy Potential

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Skyrocketing energy prices and concerns about energy security and climate change have sparked interest in alternatives to transport systems run on fossil fuels. In recent years, electric vehicles have emerged as the preferred alternative thanks to the environmental benefits of zero tailpipe emissions and the vehicles' ability to take power directly from the power grid. (See Table.)

In the same way that a cell phone or computer runs on its battery when someone is on the go and is then plugged in when the person is at work or at home, an electric vehicle will run on battery power when someone is driving and can be plugged in at night or while the owner is at work to recharge, drawing about as much power from the grid as a dishwasher would. The main change will be no more trips to the gas station and extra money in drivers' pockets. At current U.S. electricity prices, running an electric vehicle would cost the equivalent of 75¢ a gallon (20¢ a liter).[1]

This ability to "fuel" electric vehicles directly from the existing power grid raises questions about how much additional generation capacity would be required to meet increased demand for power if there were widespread use of electric vehicles. In particular, people promoting the transition to an energy system based on renewable sources are concerned about whether such forms of energy can meet growing power as well as transportation needs.

Fortunately, there is more than enough renewable energy to do both. For instance, concentrating solar power plants built on less than 0.3 percent of the deserts of North Africa and the Middle East could generate sufficient energy to meet the local needs of these regions as well as the electricity needs of the entire European Union. One effort to tap this potential is the DESERTEC Concept, which envisions 100,000 megawatts (MW) of concentrating solar power plants being developed in North Africa and the Middle East by 2050 and transported via underwater cables across the Mediterranean to Europe. Algeria already has plans to build a 3,000-kilometer cable to Germany, allowing it to export 6,000 MW of solar thermal power by 2020 and providing a perfect complement to Germany's significant wind energy capacity.[2]

The renewable energy potential in the United States is similarly vast, and only a small fraction of it would need to be harnessed to electrify the current fleet of cars and light trucks (which account for more than a third of the total world vehicle fleet). If half of the light vehicle fleet were plug-in hybrid electrics, a transformation that is likely to require several decades, an increase in U.S. wind energy capacity of roughly 105,000 MW would be needed to run the vehicles. This is equivalent to total

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global wind capacity today and could be supplied by the addition of 63,000 5-MW wind turbines. (These vehicles would still rely on gasoline for longer trips, depending on individual driving and charging behavior.) A 2008 U.S. Department of Energy report concluded that wind power could supply 20 percent of U.S. electricity by 2030, or more than 300,000 MW—which is almost three times as much electricity as is used to run half the country's light vehicles today. And—unlike oil—the sun, wind, water, and biomass needed to produce renewable energy are available throughout the world. [3]

As an additional benefit, existing manufacturing facilities (some of which are now idle) could be converted to produce wind turbines, creating thousands of green-collar jobs. China provides an example of a booming wind manufacturing industry, which is set to produce 11,000 MW of turbine capacity (or more than 7,000 1.5-MW wind turbines) in 2008. And Chinese companies are beginning to export their turbines as well.[4]

Are there benefits to using renewable energy to power electric vehicles in addition to the cleaner air and reduced acid rain–forming emissions that would result? The government of Denmark thinks so and is now looking to lead in the move toward electric vehicles. Wind accounted for 21 percent of Danish power production in 2007. Since wind speeds are higher at night, when electricity demand is lower, Denmark has looked for ways to offload its excess generation. Electric vehicles could help here, as most of them will be charged at night and will be able to make use of excess wind energy. As Torben Holm of Danish Oil and Gas has noted, "by charging the cars at night Denmark will be able to use wind energy that otherwise would have to be exported to neighboring countries, typically at relatively low prices. Moreover…that energy can be sent back to the grid during peak hours."[5]

Working with the Danish government to make this vision a reality is an Israeli-American start-up company called Better Place. It plans to provide electric vehicles and countrywide electric recharge grids in both Israel and Denmark beginning in 2009 and expects to have 100,000 vehicles in place in each country by the end of 2010. The electric recharge grid would include recharging points for drivers but also battery exchange stations where they could swap depleted lithium-ion batteries for fully charged ones for trips of longer than 120 miles (200 kilometers), the projected range of these vehicles, thus eliminating concerns about the limited range of full electric vehicles. The cars in Israel and Denmark will rely on solar and wind power respectively, providing truly clean transportation. Better Place is currently discussing similar projects with 25 countries.[6]

Key to the implementation of this plan is the development of vehicle-to-grid technology. Switching electric vehicles to this system would create a large, flexible, distributed power generation, storage, and transmission network, eliminating the need for other means of energy storage as well as reducing the need for new transmission and distribution infrastructure.[7]

Google is already putting this approach into practice at its California headquarters, using a fleet of six plug-in hybrid electric vehicles and a 1.6-MW solar array that currently feeds power into the California grid. Google plans to eventually include 100 plug-in hybrid electric vehicles in its fleet and to install solar charging stations so that these vehicles can be charged from Google's solar array. The company has conducted a successful demonstration of vehicle-to-grid technology in cooperation with the utility company Pacific Gas & Electric. These vehi-

Electric Vehicle Technologies

Technology	Description
Hybrid electrics	Have an electric motor as well as an internal combustion engine; not able to plug in to recharge
Full electrics	Solely battery-powered; recharged by plugging into main electricity source
Plug-in hybrids	Combine batteries, which allow them to run in electric mode, with smaller internal combustion engines (which use gasoline or other liquid fuels) to power the vehicle on longer trips when battery power has been depleted; recharged by plugging into main electricity source
Vehicle-to-grid	A form of smart grid technology that allows utilities to communicate with vehicles as they would larger power plants, with energy able to flow in both directions and the vehicle owner debited or credited for energy taken from or provided to the grid

cles will be able to store energy produced from Google's solar array for later use or to supply additional power to Google or the grid during peak demand hours. After their first year on the road, the cars in the Google fleet are getting an average of 93.5 miles per gallon of gasoline.[8]

Building on this interest in electric vehicles, major automakers such as General Motors and Nissan-Renault have plans to market full electric vehicles or plug-in hybrid electrics within the next two years. Smaller automakers such as REVA of India and BYD Auto of China are also getting in on the game, with plans to have electric vehicles on the market both at home and in Europe and North America in the next two years as well. The electric range of these vehicles should be 40–100 miles (about 65–160 kilometers), with prices that are competitive with today's mid-range vehicles.[9]

Plug-in hybrid electrics provide an alternative that eliminates concerns related to the limited range of fully electric vehicles. This flexibility does come with increased emissions, however, although they are still far below those produced by cars run just on gasoline. The relatively lower emissions are due to the fact that 71 percent of cars in the United States are driven for at most 40 miles a day in weekday travel, a distance that could be driven entirely in electric mode in most plug-in hybrid electrics (assuming that the vehicles are recharged every night for the next day's driving), with gasoline only being used by people driving beyond the vehicle's electric range each day.[10]

In many countries, powering vehicles with the existing electricity mix would mean that much of the energy would come from coal. But even in the worst-case scenario of using 100 percent coal-fired electricity, the carbon dioxide emissions associated with electric vehicles are expected to decline—up to 50 percent by some estimates—relative to those of gasoline and diesel-fueled vehicles because electric motors are three to four times more efficient.[11]

The chief barrier to wider use of electric vehicles is the lack of political will. To date, the private sector has driven the transition, but governments can greatly accelerate it through preferential taxation of electric vehicles, higher taxes on gasoline and diesel, and public incentives and research to advance technologies and infrastructure.

Another barrier to deployment is current battery technology. The nickel–metal hydride

Better Place

The Better Place electric car prototype

batteries installed in most current hybrid-electric vehicles are limited in both power and energy storage density. But the development of lithium-ion batteries promises significant improvements. These are becoming the industry standard due to their higher energy and power densities and lower cost, and most automakers are banking on them to provide the necessary extension in driving range for the next generation of electric cars and plug-in hybrids.[12]

An infrastructure needs to be created to ensure that drivers can easily charge their vehicles wherever they happen to be. Public and private investment is also required to develop the "smart" grid technologies needed to ensure that all new plug-in hybrid electric and fully electric vehicles are vehicle-to-grid capable and that electricity grids can handle the demands of these vehicles. As hundreds of thousands of electric vehicles hit the roads, their charging patterns will have to be actively managed to reconcile the needs of drivers and grid operators.[13]

Electric vehicles have a great potential to help reduce the impact of transportation systems on the environment. But it is important to remember that their adoption must be seen as a part of a larger process of moving toward a more sustainable transportation system. A holistic approach to future transport must include not only electric vehicles but also the promotion of better urban design, walking, cycling, and carpooling as well as increased investment in public transit and rail—programs that will lead to less driving and a more efficient transit system. And that will help the world meet sustainable mobility goals with renewably generated energy sooner.

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