THE GNCS FACTSHEETS

Electric Vehicles

The transport sector accounted for over 6,400 million tons of carbon dioxide ($MtCO_2$) emissions in 2008, amounting to almost 19% of global emissions that year.[1] According to the International Energy Agency (IEA), global emissions from road transport will increase by a third by 2035, especially due to growth in China and India's automobile markets.[2] Amongst the different options to mitigate road transport emissions, all-electric vehicles (EVs) offer the most promising alternative in the sense that they have no tailpipe emissions. There were a little less than 390,000 EVs on the road around the world in 2008,[3] with approximately 57,000 in the US.[4] The current state of EV technology, its high cost and its hefty infrastructure requirements have impeded EVs from further penetrating the market to date.

Status of the Technology

Vehicles. All-electric vehicles, unlike hybrids, do not contain an internal combustion engine. They depend on one or several electric motors, powered by the vehicle's battery, which is charged by plugging the car into an electrical device that gets power directly from the grid.[5] EVs are simpler to produce than hybrid vehicles because they do not require the incorporation of both an electric motor and an internal combustion engine. However, they have had limited market penetration, mainly due to technological shortcomings such as low range (due to limited battery capacity), long charging time or low maximum speed. More recent EV models have shown some progress: the all-electric Nissan Leaf, for instance, which entered the market in December 2010, can reach 90 mph carrying 5 passengers.[6] However, with a range of 100 miles per charge, it cannot accommodate long distance traveling. Another fundamental obstacle to the widespread adoption of EVs remains their high prices.[7]

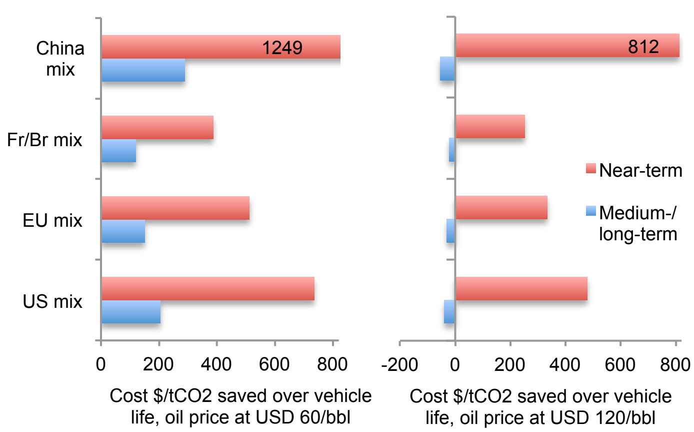
Batteries. There are two principal characteristics that determine the EV battery's performance: its energy density determines the car's achievable range per charge; while its power density governs the vehicle's acceleration capacity. To date, lithium-ion batteries have achieved the highest energy and power density, and are used in all new EV models.[8] Recent research has shown that the current theoretical boundaries of lithium-ion batteries could even be exceeded in the near future.[9] Battery life is also essential in determining the cost of EVs and their capacity to enter the market. Charging and discharging lithium-ion batteries – a process called cycling – has an adverse effect on their health, especially when batteries are either at a very low state of charge, or maintained at a high state of charge for a long time. Recently, battery reserves have been incorporated at the low and high ends of the state of charge, so that batteries are never completely discharged or overcharging.[10] While such improvements are crucial for the widespread use of EVs, they necessarily increase battery costs, which are largely responsible for the high price of EVs. In 2009, industry estimates put the cost of lithium-ion batteries at about $600 per kilowatt-hour (kWh), which places the average cost of a 30 kWh battery at around $18,000.[11]

Infrastructure. The existence of both privately owned and publicly accessible charging infrastructures is crucial to support the deployment of EVs. However, this will be very costly: required infrastructure investments are estimated at around $30 billion for a 10% market penetration.[12] It also poses a number of questions: Who

[1] IEA. (2010). *World Energy Outlook 2010.* Paris: International Energy Agency.
[2] *Ibid.*
[3] IEA. (2011). *IEA Implementing Agreement on Hybrid and Electric Vehicles: Number of EVs and HEVs in Different Countries* [online]. See: http://www.ieahev.org/evs_hevs_count.html.
[4] EIA. (2011). *EIA Renewable Energy – Estimated Number of Electric Vehicles in Use* [online]. US Energy Information Administration. See: http://www.eia.gov/cneaf/alternate/page/atftables/attf_v10.html.
[5] Electrification Coalition. (2009). *Electrification Roadmap–Revolutionizing Transportation and Achieving Energy Security.* Washington D.C.
[6] Nissan. (2010). *Nissan Leaf Electric Car: 100% Electric. Zero Gas. Zero Tailpipe* [online]. See: http://www.nissanusa.com/leaf-electric-car.
[7] The Nissan Leaf is priced at over $26,000 net value after tax savings.
[8] They can achieve theoretical energy densities ranging from 50 to 175 watt-hours per kilogram and power densities of 10 to 9,000 watts per kilogram (Electrification Coalition, 2009).
[9] Patel, P. (2009). "Nanowire Advance for Lithium Batteries." *MIT Technology Review*. 14 Aug 2009; Greimel, H (2009). "Toyota Improves Lithium-Ion Batteries." *Automotive News Europe*. 20 Aug 2009.
[10] Electrification Coalition (2009).
[11] *Ibid.*
[12] Electric Vehicle Update. (2011). *Demand Planning for EV Charging Infrastructure Investment* [online]. See: http://analysis.evupdate.com.

will pay for public charging infrastructure? Who will own and operate the charging stations? How many chargers should be deployed and where? Who should provide the electrical power and at what rate? A comprehensive network of charging facilities will need to be supported by domestic policies, since consumers will not buy EVs without the infrastructure in place and private investors will be reluctant to construct charging points in the absence of guaranteed demand.[13] An Israeli company, Better Place, offers an alternative known as the network operator model. It proposes constructing dense networks of charging spots and battery-switch stations, incorporating battery and infrastructure expenses into the company's cost structure, and offering subscriber fees to EV owners based on mileage.[14] This would mean that the company could be profitable while it builds the infrastructure. Moreover, battery-switch stations – in which a car's depleted battery is replaced with a fully charged one within minutes – could potentially eliminate the bottlenecks of long charging times and low range.

Cost of EVs per ton of CO_2 saved at \$60 and \$120 oil prices



Source: Authors, from IEA (2009)

Note: The four electricity generation mixes are: (1) China: high carbon intensity coal; (2) France/Brazil: low carbon nuclear or renewables; (3) OECD Europe: more diverse, with natural gas and renewables; (4) the US: diverse, with high coal usage.

Abatement Potential and Cost

The IEA estimates that current EVs present an added consumer cost of \$7,500 per vehicle.[15] However, they result in lifetime GHG savings of 15–40 tCO_2-equivalent per vehicle.[16] The figures above show estimated near-term and medium- to long-term marginal abatement costs (cost per ton of CO_2 saved) over the vehicle lifetime, depending on projected oil prices and different electricity generation mixes. The dirtier the electricity used to power EVs, the higher the marginal cost becomes – reducing emissions in the power sector is even more crucial with the adoption of EVs. Meanwhile, with a high oil price (\$120/bbl), medium to long-term costs are negative.

Policy for the Future

Electric cars currently occupy a niche market, which will help encourage their future spread, as well as economies of scale and learning. But it is unlikely they will replace gasoline cars without the support of policy. Different forms of tax credit systems provide incentives for consumers to purchase EVs rather than internal combustion engine vehicles at the domestic level. However, these tax rebates are often low and their incentives not powerful enough. Domestic or international pricing mechanisms to raise the costs of buying internal combustion engine cars are also an option to encourage the adoption of EVs. This can be achieved either by putting a higher price on gasoline or by setting an effective price on emissions. For example, car emissions could be paid by consumers on a per kilometer basis.

For EVs to travel internationally, vehicles, batteries and charging infrastructure would need to be compatible across national boundaries. This would also generate network effects, encouraging the further adoption of EVs. Ultimately, this suggests the need for global standards. The standardization of EV technology is discussed within the IEA Implementing Agreement on Hybrid and Electric Vehicles, which comprises fourteen countries, including the US.[17] Furthermore, an international agreement with the goal of making EVs a global standard could provide the adequate market signals and network effects for a large-scale transition from internal combustion engine vehicles to EVs. This does not seem likely today, as EV technology is not yet mature, and its costs still too high.

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Further resources are available at **www.theGNCS.org**

[13] *Ibid.*
[14] Better Place. (2011). *A Comprehensive Electric Vehicle Solution* [online]. See: http://www.betterplace.com/the-solution.
[15] IEA. (2009). *Transport, Energy and CO2: Moving Toward Sustainability*. Paris: IEA. For 150 km range EVs with a lifetime of 15 years.
[16] *Ibid.*
[17] IEA. (2011). *IEA Implementing Agreement on Hybrid and Electric Vehicles* [online]. Available at: http://www.ieahev.org/index.html.