Community Infrastructure for the Electrification of Transportation

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Abstract

Parking lots with solar-powered charge stations for plug-in electric and plug-in hybrid electric vehicles have the potential to improve air quality human health, and local employment. The shade provided by the solar panels and the convenience associated with charge stations in parking lots where people work, shop, eat, and relax have social value. A significant fraction of electric power production can be generated by solar panels that provide shaded parking.

The electrification of transportation with power provided by wind and solar energy has the potential to reduce engine exhaust emissions and improve air quality. The health impacts associated with engine exhaust include increased risk of cancer, heart attack and stroke. The costs associated with air quality impacts have been estimated to be as large as 10 cents per mile in some urban environments.

Electric engines are much more efficient than internal combustion engines. Energy operational costs with electric engines are about 1/3 of the fuel cost of internal combustion engines.

Solar-powered charge stations are an important smart growth option for many communities. There are several business models that may be used to develop the infrastructure needed to support plug-in electric vehicles that are presently available and those coming soon.

Introduction

The International year of "Sustainable Energy for All" began in January 2012, and the United Nations wants governments, the private sector, and civil society to increase the use of renewable energy, improve efficiency, and expand energy access (UN, 2012). One of the significant community sustainable development challenges is to reduce greenhouse gas emissions by making greater use of sustainable energy sources. The electrification of transportation is a significant opportunity to greatly reduce petroleum consumption and greenhouse gas emissions. The infrastructure that is needed by consumers with electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) includes charge stations at many locations. This manuscript will focus on solar-powered charge (SPC) stations, their locations, business models for them, and their operation in a smart grid system.

In order to reduce carbon emissions by 80%, Williams et al (2012) point out that transportation must be powered electrically and that electric power must reduce its dependence on fossil fuels. Solar and wind energy are two important sources of renewable power, and there is continuing progress toward the reduction of cost while costs of petroleum have been increasing. New developments in batteries will also contribute to the electrification of transportation.

Communities that approach sustainable development with a view to the triple bottom line that includes social value, environmental impacts, and financial considerations will find many reasons to install SPC stations at many locations in the community.

Social Value Considerations

Many plug-in hybrid electric vehicles (PHEVs) currently have a range of 25-80 miles in which they can be operated with electrical power from the batteries. Solar-powered charge (SPC) stations at many different locations that allow PHEV owners to plug in at work, shopping centers, restaurants, gyms, parks, etc. will have convenience as a social value. If the PHEV is shaded by a solar panel, this has social value as well. The cleaner air associated with electrification of transportation also has social value both with respect to the pleasant environment and the better health of those who breathe the air.

Reducing reliance on fossil fuels has great potential social value when viewed from a life cycle perspective. In 2006, Matthew Chen reported that China's efforts to secure foreign oil and natural gas to meet its growing energy demand are contributing to massive human rights violations in Sudan and Burma [Chen, 2006]. In 2009, Amnesty International reported that the oil industry in the Niger Delta of Nigeria brought impoverishment, conflict, human rights abuses and despair to the majority of the people in the oil-producing areas [Amnesty International, 2009]. The oil industry is addressing human rights and ethics [IPIECA 2008]. However, it seems clear that the high global demand for petroleum is a factor in human rights violations in some countries.

Environmental Considerations

Recently Dr. Gro Harlem Brundtland presented the 2012 John H. Chafee Memorial Lecture and said "Today, we face at least three fundamental challenges to human security and well-being: poverty, ecosystem degradation and climate change. All of these challenges are connected." (National Council for Science and the Environment, 2012; DeLong, 2012). Climate change is already costing billions of dollars, and it is a major national and international security issue because of its impacts on people in the United States and other parts of the world (Goodman, 2012). United Nations Secretary-General Ban Ki-Moon has placed "Sustainable Energy for All" at the center of the international agenda (UN, 2012; National Council for Science and the Environment, 2012). One of the important reasons to install SPC stations is to reduce greenhouse gas emissions associated with electric power generation and transportation.

Reduced emissions from vehicles would help many urban communities meet air quality standards. There are health costs associated with air quality in terms of quality of life and health care costs. In two recent studies by Wellenius et al. (2012) and Mills et al (2011), investigators found that the risk of heart attack and stroke increases with an increase in concentration of air pollutants associated with vehicle emissions, and that small particulates from combustion engines induce vascular effects. Kunzli (2011) points out that there is significant public health value to efforts to further reduce small particulates related to combustion of vehicle fuels. In June, 2012, the International Agency for Research on Cancer classified diesel engine exhaust as carcinogenic to humans. This is based on sufficient evidence that exposure to diesel engine exhaust is associated with an increased risk of lung cancer. Gasoline engine exhaust was classified as possibly carcinogenic to humans (Benbrahim -Tallaa et al., 2012, World Health Organization, 2012). Mashayekh et al. (2011) have estimated the economic impact of air

emissions from vehicles in urban environments; values range from 4.2 cents per mile to 10 cents per mile for the top 10 urban areas of the United States. Thus, the electrification of transportation with SPC stations will improve air quality, reduce health costs, and improve public health. Using solar and wind power to charge batteries is much better than using electricity from coal, because coal fired power plants have substantial emission impacts (Michalek et al., 2011). Life cycle analysis shows that the emission costs associated with coal powered electrical energy for an EV are more than $5000 over the life of the EV (Michalek et al., 2011).

Economic Issues

It is well known that petroleum supplies are limited and that the cost of crude oil production has increased over the last 50 years. There is a need to make use of solar and wind power for transportation in order to conserve fossil fuel resources. One benefit of using electrical energy for transportation is that it will reduce the amount of crude oil that is used. Future price increases of petroleum may be mitigated to some extent if there is significant electrification of transportation, because this will extend the supplies of petroleum. Liquid fuel alternatives such as biofuels cannot sustainably meet more than 20% of the current U.S. demand for fuel for transportation (Williams et al., 2012). Oil dependence costs have been estimated to exceed $500 billion per year (Green, 2012) and military costs associated with the Persian Gulf are estimated to be about $500 billion per year (Stern, 2010). When these costs are considered the full cost of gasoline is at least two dollars per gallon (6 cents/mile) more than the price paid at the pump (VTPI, 2012).

There are significant costs associated with greenhouse gas emissions. Climate change associated with increased concentrations of carbon dioxide in the atmosphere is a major concern. The future cost of climate change is expected to be very great and a major reason why it is important to develop SPC stations (Stern, 2007). Nicholas Stern (2007) advocates action now to reduce future costs of climate change. Goodman (2012) points out that the costs of climate change and weather related events have been increasing with time; there were 12 extreme weather events that each cost more than $1 billion in 2011 (Goodman, 2012). More than 6000 heat records in the U.S. were broken in 2011. The Victoria Transport Policy Institute has estimated costs associated with climate change to range from 0.9 to 2.8 cents per mile for automobiles with gasoline engines (VTPI, 2011). Developing and installing SPC stations with shaded parking will help to reduce future costs associated with climate change.

Electricity is more costly at peak times such as mid-to-late afternoon in summer. The mid-afternoon when power demand is greatest is a time when the power from the solar panels is substantial. Many parking lots full of solar panels, charge stations, and EVs can be used to help meet this peak power requirement by managing the flow of power to the grid and the EVs such that the power flows to the grid at times when the power is needed to meet peak power needs. Using the solar power production for peak power when it is needed for that purpose provides an economic value. This economic value is associated with the ability of the utility to optimize the operation of the SPC station system such that EV charging is managed as part of a larger grid.

The energy losses and cost of transmission are less when the power generation and use are close to each other. The electrification of transportation has the potential to increase electrical energy use significantly, but fewer new transmission lines will be needed if a significant fraction of the

electrical power for transportation is produced close to where it is consumed, such as at SPC stations.

Employment in the United States will be positively impacted by the installation of SPC stations. The electrical power from the solar panels will be produced locally and most of it will be consumed near where it is produced. Many jobs will be provided to those who install, service, and manage the SPC stations, and for the manufacture and shipping of the supplies that are needed. There may be about $4 trillion of economic activity associated with 200 million SPC stations, costing about $20,000 each over a 20 year time period. The 200 million SPC stations would produce about 1.2 billion MW hrs/year, which can be compared to 4.125 billion MW hrs/year of electrical energy generated in 2010 (U.S. Energy Information Administration, 2011). The energy from an average, 15%-efficient solar panel at latitude tilt (40 degrees), with area sufficient to cover one parking stall (27 m^2) would be about 16 kW hrs assuming 4 peak sun hours per day, a typical annual average for the U.S. midcontinent. Since there is a need to have more available charge stations than customers needing them, only a portion of the power would be used to charge batteries in EVs and PHEVs. The energy that flows into the grid will satisfy nearest loads.

If many SPC stations can be installed and put into service, this will be beneficial to owners of EVs. The availability of charge stations will encourage and benefit the market penetration of EVs.

Business Models

There are a number of aspects associated with the manufacture, installation, and management of the SPC stations. The plug-in hybrid electric vehicles have a range of about 25-80 miles using the electric option. This will work best if individuals can plug-in at many locations. The cost of charging a 10 kW hr battery at 10 cents/kW hr is one dollar. In many free parking locations, the option of free shaded parking with free charging should be considered. The cost of the SPC station can be paid for by sales taxes or income from purchases at nearby stores. At locations where individuals already pay to park, the shaded charge stations can be added and the cost of parking can be adjusted to include the additional benefits. Multiple entities may need to be involved in the installation of SPC stations to take advantage of the renewable energy credits and the tax incentives. The utility, parking lot owner, parking lot manager, and the customers need to find ways to work cooperatively to share the benefits that are available.

Finally, there is a delicate balance of demand and supply that must be negotiated: people will be reluctant to commit to PHEVs if there is not enough of a charging infrastructure, and sites will be reluctant to commit to SPC stations if there are not enough PHEVs to make good use of them. These supply and demand considerations can have positive feedback effects on each other, but that cycle must be initiated somehow. Since the power produced at SPC stations can be fed into the grid and the shade can be beneficial for any vehicle, there are immediate benefits even if the charge stations have only modest use. The installation of SPC stations should move forward so that this infrastructure is available for use by drivers of PHEVs.

Significant growth in the percentage of vehicles that are EVs and PHEVs can happen, for example, by PHEVs reaching clearly lower operating costs relative to gasoline vehicles (cost

parity is not sufficient, because there is a status quo inertia favoring gasoline vehicles and their existing infrastructure).

Conclusions

Many reasons to move forward with the installation of SPC stations for electric vehicles and plug-in hybrid electric vehicles have been presented. Because many new plug-in vehicles are being introduced in 2012 and 2013, increasing the demand for charging stations, now is a good time to move forward with SPC station technology. There are significant social, environmental, and health benefits.

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