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Electric Vehicle Sustainability

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Abstract:
Many perceive electric vehicles (EVs) to be eco environmentally sustainable because they are free of emissions of toxic and greenhouse gases to the environment. However, few have questioned the sustainability of the electric power required to drive these vehicles. This paper presents an in-depth study that indicates that massive infusion of EVs to our society in a short time span will likely create a colossal demand for additional electric power generation much beyond what the US electric power generating industry can provide with its current generating capacity. Additionally, such demand would result in much adverse environmental consequences if the current technology of electric power generation by predominant fossil fuels continues. Other rarely accounted facts on environmental impacts by EVs are the substantial electric energy required to produce batteries that drive EVs, and the negative consequences relating to the recycling of spent batteries.

Index Terms: Electric and hybrid vehicles, electric power generations, energy for EV, HEV and batteries, emissions, green house gases, sustainable development.

I. INTRODUCTION

There is an unprecedented surge of interest in and the desire of producing gas-electric hybrid (HEVs) and all-electric vehicles (EVs) by the governments and public in the industrialized countries. This surge of interest and desire is attributed to several factors relating to the life-threatening air pollution in many parts of the world, the high petroleum price, conflicts in oil producing Middle East regions and the alarming trend of global warming due to rapid increase of greenhouse gas emissions by all sources, including those from transportation. All the financial supports and the incentives for owning EVs are based on the perception that EVs are eco-environmentally sustainable means of transportation of the future. The concept of design and construction of electricity powered automobiles is by no means new. Active research and development in EVs to replace gasoline powered vehicles can be traced back to the early 1970s amidst the first, but short-lived energy crisis in this country triggered by unilateral control of oil production and price set by the OPEC cartel (OPEC = Organization of the Petroleum Exporting Countries). There was a strong desire to produce non-gasoline powered vehicles by the automotive industry in this country, and EVs are among the top choice by this industry. Unfortunately, this desire diminished soon after consumers' acceptance of high petroleum price as a "fact-of-life." The next wave of strong interest in producing EVs did not occur until late 1980s resulted from the worsened air pollution in many urban centers in the world. The term "sustainable development" initiated by the United Nations [1] also renewed strong interest by citizens of industrialized countries in the increasing use of renewable energy sources for sustainable economic development. Because transportation consumes about 28% of total energy consumed in US and other industrialized nations [2], and it is also a major contributor to air pollution in major urban centers, EVs that are powered by "clean" electricity are perceived to be a viable sustainable means of transportation by industrialized countries. Consequently, the giant U. S. auto-maker, the General Motor Corporation pioneered in the design and construction of a battery power vehicle called EV1 in 1996 in responding the renewed public interest. Unfortunately the EV1 vehicle never actually caught on by the consumers. It was subsequently removed from the marketplace three years later. There were a number of reasons for the failure of this venture, as described in a well publicized documentary movie on "Who Killed the Electric Car" [3]. Fortunately, the strong desire in eco-environmental sustainability, and the pressing needs to mitigate greenhouse gas emissions by automobiles have sustained the continuous effort in developing EVs that would be economically viable, as well as marketable enough to replace most or all gasoline-powered vehicles in the new millennium. This paper will address a serious but rarely publicized issue on whether EVs are indeed eco-environmentally sustainable means of transportation for the US with the prevailing technologies used in generating electric power that is required to drive these vehicles. There is no qualm about EVs being emissions free as far as eco-environmental sustainability is concerned. However, the electricity that is required to produce and charge the batteries for the EVs is generated by predominantly fossil fuels that emit not only toxic solid and gaseous byproducts to the atmosphere, but also the greenhouse gases for global warming. A conservative estimate based on slight outdated available information on the required additional electric energy to substitute all gasoline-powered vehicles with EVs is staggering; it indicates an equivalent additional electric energy required to produce the batteries and drive all household gasoline-powered vehicles in the US in 2001 would exceed the total electric power generating capacity by all US utilities combined in the entire Year of 2005. The potential adverse effects to eco-environment by massive infusion of EVs in the U.S. with prevalent electricity generation technologies are beyond anyone's imagination. One may thus perceive that the sustainability of EVs is inseparable to the sustainability of electric power generation required to power these vehicles. EVs can be viewed as sustainable means of transportation only when the electricity that is required to drive them can be generated by clean renewable energies such as hydroelectric power, hydrogen fuel cells,

hybrid solar photovoltaic and wind power, and ultimately nuclear fusion. The issue on effective recycling of millions spent batteries also needs to be dealt with if EVs will indeed be eco-environmentally sustainable.

II. SUSTAINABLE DEVELOPMENT:

The term "Sustainable Development" is a universally accepted solution to economic development of humankind for the present and future generations. It is a socio-economical process characterized by the fulfillment of human needs while maintaining the quality of the natural environment indefinitely. The concept of sustainable development came to general public awareness following the publication of a 1987 report by the Brundland Commission established by the UN General Assembly in 1983 [2]. Figure 1 illustrates the three principal pillars of sustainable development: "Social justice," "Environmental protection," and "Economic development." The pillars on "Environmental protection" and "Economic development" appear self-explanatory. The pillar on "Social justice," however, advocates the health and sustainability of social structure resulted from economic growth. These three pillars are equally important in implementing sustainable development as they are interrelated by "equitability," "bearability," and "viability" as indicated in Figure 1. Figure 1 Three Pillars of Sustainable Development The implementation of sustainable development requires the consumption of renewable resources provided by nature be kept less than what it can provide. Renewable resources include energy, quality air and water, as well as productive soil, ecoforestry, marine lives and all biospecies

III. ENERGY CONSUMPTION BY GASOLINEPOWERED VEHICLES

The total energy consumption in the US in 2005 was 29,000 TWh [2] (or 27,864 TWh in 2012). Of this amount of energy consumption in 2005, 28% was consumed by the transportation sector. It also indicated that 61% of that amount was by gasoline fuel. Thus, we may estimate the approximate energy consumed by gasoline-powered vehicles to be 29000 TWh x 0.28 x 0.61 = 4953 TWh – a staggering amount! If we view this amount of energy to be what was consumed by automobiles in that year, we would come up with a hypothesis on how much equivalent electric power would be required to convert all these gasoline-powered vehicles into EVs. This hypothesis obviously is not realistic because the total electric power generation in the US in that year was only 4055 TWh. Conversion of all gasoline-powered vehicles to EVs in that year would require US utilities to generate equal or more than double their generating capacity. Another set of statistical data [4] indicates that the household vehicles in the US consumed 113.1x109 gallons of gasoline in 2001. By using a conversion factor of 114000 Btu/US gallon of gasoline and 1 Btu = 0.2929 Watt-hour (Wh), we would reach an amount of 3778 TWh of energy.

IV. ENERGY REQUIRED IN PRODUCTION OF BATTERIES FOR EVS:

Batteries are essential parts for any electric vehicle (EV) or plug-in hybrid gas-electric vehicle (PHEV). They amount to 20 to 40% of the total mass of typical EVs [5]. So they consume significant amount of driving power of the vehicles. Battery innovations are the key to making PHEVs more eco-environmentally sustainable because lighter and easier-to-recharge batteries will improve efficiencies of these vehicles. They could also spark mass produced PHEVs and even resurrect the idea of all electric vehicles.

There are three issues related to the batteries in the sustainability of EVs:

1) The energy required to produce batteries,

2) Emissions in producing batteries, and

3) Energy and environmental consequences in recycling consumed batteries.

There are two ways one may estimate the energy required to produce the two kinds of batteries listed in Table 1 based on the estimated 4953 TWh energy required to replace all gasoline-powered vehicles derived from available data for 2005, or the 3778 TWh equivalent electric energy consumed by gasoline-powered household cars in 2001, as presented in Section III.

1) Method A: By using the estimated 115 kWh energy for each of the emerging EVs as calculated above, we will come up with an equivalent number of 43.07x109 EVs based on the 2005 statistics, or 32.85x109 EVs based on the 2001 statistics. On an assumption that each EV carries 4 batteries and we would come up with a total 172.28x109 batteries by using the 2005 statistics, and 131.4x109 batteries using the 2001 data.

2) Method B: We may also estimate the energy required to produce batteries for EVs replacing the gasoline-powered vehicles in the following ways; Since each battery on average contains 25 kWh as mentioned above, we may estimate the total number of batteries to produce the energy required to replace all gasoline-powered vehicles in 2005 by electric power supplied by batteries as: 4953x109 /25 = 198.12x109 batteries based on statistics available for year 2005, or 3778x109 /25 = 151.12x109 batteries in Year 2001.

V. STRATEGY FOR SUSTAINABLE ELECTRIC VEHICLES:

The statistic data presented in this paper though are slightly outdated but they have adequately demonstrated that the issue on the sustainability of EVs (and PHEVs) cannot be dissociated from the sustainability of electric power generations by utilities. While much effort have already been initiated to generate electricity by clean coal technology [8] with smart grid distribution systems for efficient power transmission and distributions [9], a great deal more effort is required to produce electricity by clean renewable energy sources such as solar and wind. A new US government initiative on "20% wind energy by 2030" [10] targets having 20% of the electric power generated by this country is from wind energy. The same goal was set by the US based photovoltaic idustry [11]. Solar and wind are only two known clean eco-environmentally sound energy sources for electric power generation. Current national goals for having electricity generation by both these clean renewable energy sources thus appears to be 30% of the toal electricity power generation by these sources by Year 2030. If one uses the 4055 TWh electric energy generation by the US utility in 2005 as a base line capacity, we would expect 30% of that amount, i.e. 1216 TWh by solar/wind power combined by Year 2030. This would mean 1216/4953 = 0.25 or 25% of all household gasoline-powered vehicles in that year could be covnerted to EVs without producing additional environment-threatening emissions, and thus sustainable vehicle conversion. This rate of gradual introduction of EVs and PHEVs to the US market would allow the utilities in this country with the necessary time to supply additional electric power generation by clean renewable energy sources required to drive EVs and PHEVs for the US consumers.

VI. RESULTS AND CONCLUSION:

A rather conservative estimate based on slightly outdated available information on the required additional electric energy for replacing all gasoline powered vehicles to EVs is staggering; it indicates an equivalent additional electric energy of 3778 TWh required to replace all household gasoline-powered vehicles in the US in 2001 with EVs, with additional 1236 TWh electric energy required to produce the batteries for these EVs. The total additional electric energy required for such replacement would

exceed the total electric power generating capacity of 4055 TWh by all US utilities combined in the entire Year of 2005. The consequence of the staggering additional electric energy required to power large scale new EVs as presented above is just one factor, other issues relating to haste introduction of EVs are the overloading the vital grid transmission of electric power as well as the patterns of peak-power generations that have been established and practiced by U.S. utilities for many years. The analyses presented in this paper though are based on slightly outdated statistical data on electric power generations and the consumption of energy by gasoline powered vehicles and electric battery productions they nevertheless have indicated that any ill planned and unregulated massive introduction of electric vehicles without thoroughly planned electric power generations and distributions by clean renewable energy would result in not only eco-environmental disaster but also in serious socioeconomic problems because of insufficient power supply to the demand by the nation's industry and business. Government, utilities and EV industry need to work together to develop a credible road map on the nation's striving towards sustainable transportation, which is vital to its citizen's livelihood and also to the eco-environment sustainability of the global village.

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