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# Electric Vehicle Charging Stations as a Climate Change Mitigation Strategy

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## **Abstract:**

In order to facilitate the use of privately owned electric vehicles by NASA Langley Research Center (LaRC) employees, charging stations would need to be made available to LaRC employees. The implementation of charging stations would decrease the need for gasoline thus decreasing CO<sub>2</sub> emissions and mitigating climate change, improving local air quality and providing a per mile cost savings for LaRC employees. The rationale for charging stations and a charging station pilot program are described that would install stations as the need increased. A business model is presented that pays for the electricity and installation of these stations at no cost to the government. Langley could be an example for the federal government of how to integrate charging stations for climate change mitigation.

## **I. Introduction**

Greenhouse gas emissions from transportation were about 28% of total U.S. greenhouse gas emissions for 2011, making it the second largest contributor of U.S. greenhouse gas emissions after the electricity sector. Greenhouse gas emissions from transportation have increased by about 18% since 1990. This increase is due to increased demand for travel and the stagnation of fuel efficiency standards across the U.S. vehicle fleet. The number of vehicle miles traveled by passenger cars and light-duty trucks increased 34% from 1990 to 2011. The increase in travel miles is attributed to several factors, including population growth, economic growth, urban sprawl, and low fuel prices over much of this period. However, vehicle fuel economy began to improve in 2005, in part due to higher fuel efficiency standards. The largest sources of transportation-related greenhouse gas emissions include passenger cars and light-duty trucks (including sport utility vehicles, pickup trucks, and minivans). These sources account for over half of the emissions from the transportation sector which released 1800 million metric tons of CO<sub>2</sub> in 2011[EPA].

Our environment is threatened by climate change and pollution, and national leaders are starting to address this problem as stated by President Obama in his 2013 inaugural address:

“We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations. Some may still deny the overwhelming judgment of science, but none can avoid the devastating impact of raging fires, and crippling drought, and more powerful storms. The path towards sustainable energy sources will be long and sometimes difficult. But America cannot resist this transition; we must lead it. We cannot cede to other nations the technology that will power new jobs and new industries—we must claim its promise. That is how we will maintain our economic vitality and our national treasure—our forests and waterways; our croplands and snowcapped peaks. That is how we will preserve our planet, commanded to our care by God.” [Inaugural Address January 21, 2013]

Langley Research Center's (LaRC) Science Directorate performs studies on climate change and its impacts to LaRC research facilities but also how to mitigate carbon emissions that drive climate change. In order to address the threat of climate change, LaRC is researching possible ways to decrease the use of fossil fuels to reduce greenhouse gas emissions.

One possible solution is the use of battery powered electric vehicles for transportation where the electricity is generated by nuclear or clean fuel sources. The Department of Transportation [OmninStats] has determined that 51% of one way U.S. commuters travel 10 miles or less to work each day which makes electric vehicles attractive due to their currently short range. Although electric vehicles are environmentally advantageous, they only made up 3.3 percent of vehicles on the road in 2012 [Read 2013]. Charging stations for these vehicles are equally scarce. However, making the switch to electric vehicles would decrease CO<sub>2</sub> emissions and increase air quality [Carlsson 2010]. Figure 1 shows the rapid introduction of electric vehicles into the U.S. market [ANL]. To achieve greater acceptance of electric vehicles at LaRC, the implementation of electric vehicle charging stations is essential.

The large scale change to electric vehicles in the transportation sector has both positive and negative implications, which will be addressed here. Some of the negative issues of using electric vehicles are outlined below.

Coal is the major fuel used to produce electricity and the expansion of electric vehicles will thus produce more CO<sub>2</sub> in the atmosphere unless a comparable gasoline vehicle is withdrawn. Also it was found that cars and trucks running off the electric grid consume three times more water per mile than their equivalent gasoline powered vehicle [McKenna]. A major shift to renewable energy production would be needed to offset this increased CO<sub>2</sub> production and water use. The lithium ion batteries have an environmental impact and must be recycled in order to keep corrosive materials from entering the environment [Carter]. Current batteries do not match the energy stored in a regular tank of gasoline. So driving range is a severe problem and this coupled with a meager charging infrastructure means that drivers must carefully consider driving distance. Also in cold weather the battery driving range can be reduced as much as 30%. Charging at home is always available but to fully charge in less than four hours requires expensive equipment adding cost to the vehicle. Just like our cell phones, the vehicle batteries will eventually not accept a full charge and require an expensive replacement [Bell]. The purchase price for electric vehicles is high compared to a comparable gasoline vehicle. The price varies greatly from about \$21,000 for a Mitsubishi iMiEV to more than \$100,000 for a Tesla Roadster. Even with the maximum tax credit of \$7,500, the cost is still higher. In addition there are few auto repair shops with trained technicians that can service electric vehicles. The fuel savings somewhat offsets the higher cost [Carter].

The advantages of electric vehicles are substantial for the environment and the individual and are outlined below.

A well respected 2007 study done by the Electric Power Research Institute and the Natural Resources Defense Council analyzed the "wells to wheels" carbon emissions from driving a mile on gasoline compared to driving a mile using grid electricity. The electric vehicle had lower carbon emissions than a 25 mpg gasoline vehicle even if the electric vehicle were charged on an electric grid using mostly coal. In coastal states, such as Virginia, where power is

cleaner (nuclear) than electric vehicles will produce less carbon emissions than any gasoline vehicle reducing greenhouse gases by more than 450 million metric tons annually by 2050 (equivalent to removing 82 million passenger cars from the road). There is an abundant supply of electricity for electric vehicle transportation. A 60% U.S. market share of electric vehicles would use about 8% of the grid supply in 2050. Electric vehicles can improve air quality as well by reducing petroleum consumption by almost 4 million barrels per day in 2050 [Environmental].

While the initial cost of electric vehicles (moderated by federal tax credits) is higher than a comparable gasoline vehicle, the cost of operating the electric vehicle is substantially lower. Electric vehicles require little maintenance; brakes last longer due to regenerative braking and the cost per mile is much lower. Electricity costs from 3 to 25 cents per kWh in the U.S. but at 10 cents per kWh a fully charged Nissan Leaf costs about \$2 for 70-100 miles which for a 33 mpg conventional car and \$4 per gallon would cost \$12 [Voelcker] [Nissan]. Many electric utilities, including Dominion Virginia Power, have reduced electricity rates for charging electric vehicles at home during the night when overall electric demand is low.

All fully electric vehicles have zero emission, thus substantially improving air quality. With large numbers of gasoline vehicles emitting hydrocarbons that eventually produce ozone, a pollutant near the ground, air quality alerts are a constant summer problem in major cities. The shift to electric vehicles would substantially reduce this problem.

For the electric vehicle driver there are a number of advantages. In some states electric vehicles can use the HOV highway lanes, electric vehicles have fast acceleration and the vehicles are very quiet [Robertson].

This paper describes the preliminary design of a pilot program that would install electric vehicle charging stations at Langley. Such stations would encourage electric vehicle use by Langley employees, improve local air quality and reduce green-house emissions of CO<sub>2</sub>. The cost of the charging stations and electricity usage is completely covered in the charging fee.

## **II. Benefits of Electric Vehicles at LARC as a Climate Change Mitigation Strategy**

Approximately 7,000 cars enter LaRC every day. Assuming each of these vehicles travels approximately 20 miles per day, then nearly 140,000 miles are traveled per day by those frequenting LaRC. Additionally, the average car gets 19.6 miles per gallon [Ken Katz, U.S. Dept. of Transportation, Washington D.C. private communication] resulting in the consumption of 7,142 gallons of gasoline per day. Moreover, a single gallon of gasoline produces nearly 20 pounds of carbon dioxide [How Can, 2012]. Consequently, nearly 142,857 pounds of CO<sub>2</sub> are released into the atmosphere by vehicles traveling to and from LaRC each day. The substitution of battery powered electric vehicles would therefore result in reducing the demand for gasoline by 7,142 gallons per days and reduce CO<sub>2</sub> emissions by 142,857 pounds per day.

In addition to reducing the demand for gasoline and CO<sub>2</sub> emissions, switching to electric vehicles saves the employee money each day. For example, the Chevrolet Volt has a 16 kWh battery capacity and can travel 35 miles on a single charge [“2012 Chevy Volt Models & Specs”]. The standard electricity cost for Virginia is 12 cents per kWh. Therefore, the Chevy Volt costs \$1.92 per charge and \$0.055 per mile. Another example is the Nissan Leaf, which has

a 24 kWh battery capacity and a 73 mile range [“Nissan LEAF Versions & Specs”]. Given these values, the Leaf costs the owner \$2.88 per charge and \$0.039 cents per mile. Lastly, the Ford Focus Electric has a 23 kWh battery capacity and a 76 mile charge [“2012 Ford Focus Specifications”]. Therefore, it costs \$2.76 per charge and \$0.036 per mile. Conversely, assuming the average gasoline vehicle gets 19.6 miles per gallon and assuming \$3.60 per gallon [“Fuel Efficiency in 2012”], the average owner of a gasoline-fueled vehicle pays over \$0.184 per mile, well over three times as much as an electric vehicle owner assuming \$3.60 per gallon ([http://www.viriniagasprices.com/Prices\\_nationally.aspx](http://www.viriniagasprices.com/Prices_nationally.aspx)). The Department of Energy website [www.energy.gov/egallon](http://www.energy.gov/egallon) gives an updated cost for operation of electric as opposed to gasoline powered vehicles.

### **III. Charging Station Types**

Currently, there are three types of electric vehicle charging stations. Alternating Current (AC) Level 1 chargers have 120 volts and a max current of 12 amps. Level 1 chargers are the cheapest, but take the longest amount of time to charge an electric vehicle. Since the charger needs to provide a full charge within an 8-hour work day, they were not considered a workable option for LaRC. An AC Level 2 charger has 208-240 volts and a max current of 40 amps. The Level 2 charger can provide a full charge in three to four hours [Fox 2011]. Table 4 shows a comparison of different levels of electric vehicle charging stations. The ultimate implementation would be a solar photovoltaic array, as shown in Figure 2, generating electricity for the electric vehicle charging stations below [Baily].

### **IV. Commercial Electric Vehicle Charging Stations**

There are several commercial vehicle charging stations available. While there are multiple configurations, for this study we have chosen the dual charging station configuration. All charging stations have a standard (SAE J1772 EV) connector.

Figure 3a shows the AeroVironment EVSE-RS+. The EVSE-RS+ is a dual, 240 VAC charging station. It has an output current of 30 amps and a maximum input current of 40 amps. The dimensions are 12” width, by 12” depth by 42” height and has a 25 foot cord length.

Figure 3b shows the Charge Point CT4021 dual charging station. Similarly, it is a 240 VAC charging station with an output current of 30 amps and an input maximum current of 40 amps. The dimensions are 15” width, 12” depth and 56” height and the cord length is 18 feet.

Figure 3c shows the Schneider Electric EV230PDRR station, which is the cheapest of the four examples. Like the others, it is a dual, 240 VAC 30 Amp charging station. The dimensions are 33” width, 13” depth and 56” height with a cord length of 18 feet.

Lastly, Figure 3d shows the General Electric Dura Station NEMA3R station. Likewise, the Dura Station is a dual, 240 VAC charging station with current of 30 amps. The dimensions are 14” width, 15” depth and 51” height with a 20 foot cord.

Table 2 compares all commercial charging stations. However, the costs in the table are the retail value. NASA would receive GSA pricing, which would be lower.

## **V. LaRC Charging Station Placement and Use**

There are thirteen parking lots at LaRC being considered for electric vehicle charging stations, which can be seen in Figure 4. Most of the parking spaces on LaRC were counted and recorded in Table 1 and 10 percent, or 257, of these were considered to be reserved for electric charging vehicles in the future. Installing these charging stations would be a 5 year plan but over 15-25 years, 90 percent of the spaces could be electric charging stations.

ChargePoint by Coulomb Technologies allows for the collection of electricity usage history for public charging stations. This includes start and stop times, energy use, greenhouse gasses saved, occupied time and location. ChargePoint cards can be purchased for \$5.00 at for example the Langley Exchange. The user then can put money on the card, and the card can be used to pay for electricity at the charging station location.

The steps to starting a charging session with a ChargePoint station are very simple. Figure 5 shows a close up of a ChargePoint CT 2021 screen. To start, swipe the ChargePoint cards across the reader symbol, and the station will display a ready-to-charge message. Then, press the button on the charge connector to remove it from the holster. Finally, plug the connector into the electric vehicle. To end the charging session, swipe the ChargePoint card again, and the station will display an end-of-charge message. Then, return the connector to the holster by pressing the button on the connector.

## **VI. Business Model for Charging Fees**

In July, 2012, a bill was passed by Congress allowing the implementation of electric vehicle charging stations on federally owned property (H.R. 1402 and S-739). As long as there is no net cost to the Federal Government, this bill authorizes plans for the installation of electric vehicle charging stations for privately owned vehicles (H. R. 1402 and S-739). Therefore, the legal precedent for electric vehicle charging stations on federal property has been established.

A business model is described here that demonstrates how charging stations can be implemented at LaRC without cost to the government. The station cost is divided between electricity, installation, software monitoring and infrastructure cost. The day time LaRC electricity cost from Dominion Virginia Power is \$0.06 kilo-Watt-hour (kWh) at five percent increase due to inflation added each five years. The cost of one dual charging station is approximately \$4500. Charging stations are anticipated to last a minimum of 15 years due to the protected property at LaRC. Thus the infrastructure cost will be amortized over 10 years. Table 2 shows the retail price for each of the commercial electric vehicle charging stations, but GSA pricing should reduce the retail cost.

Table 3 shows a 15 year plan to pay for a single dual charging station. Costs include the station infrastructure, hourly electricity usage, installation and yearly electricity usage software monitoring. The infrastructure costs are assumed to be \$4,500 and will be spread over ten years. The standard LaRC electricity cost is \$0.06 per kWh. For example, a full charge of 24 kWh can be provided in four hours, and a work day is eight hours, which comes to a charge of \$2.88 per

day. Assuming employees will be accessing these stations 260 days, this results in a \$749 electricity usage charge. Installation will be approximately \$5,000 and will be spread over five years. From this, the price that LaRC would have to charge per kWh is approximately \$0.12-\$0.15 per kWh. This cost is very close to the electricity cost for current civilian electricity, thus there is no disadvantage to charging electric vehicles at LaRC. These charging stations can easily be expanded as needed, as determined by the electricity usage, which is constantly monitored for optimum operational efficiency.

## VII. Conclusion

Electric vehicles have several advantages over fossil fuel powered vehicles including reduced atmospheric carbon dioxide emission, improved air quality and lower operating cost. NASA Langley has the opportunity to be the agency leader in encouraging the use of privately owned electric vehicles, but the lack of charging stations hinders electric vehicle expansion. This study shows that a gradual program of station installation can be implemented as need arises at no cost to the government with economical electricity usage rates. Langley could be an example for the federal government in the installation of charging stations.

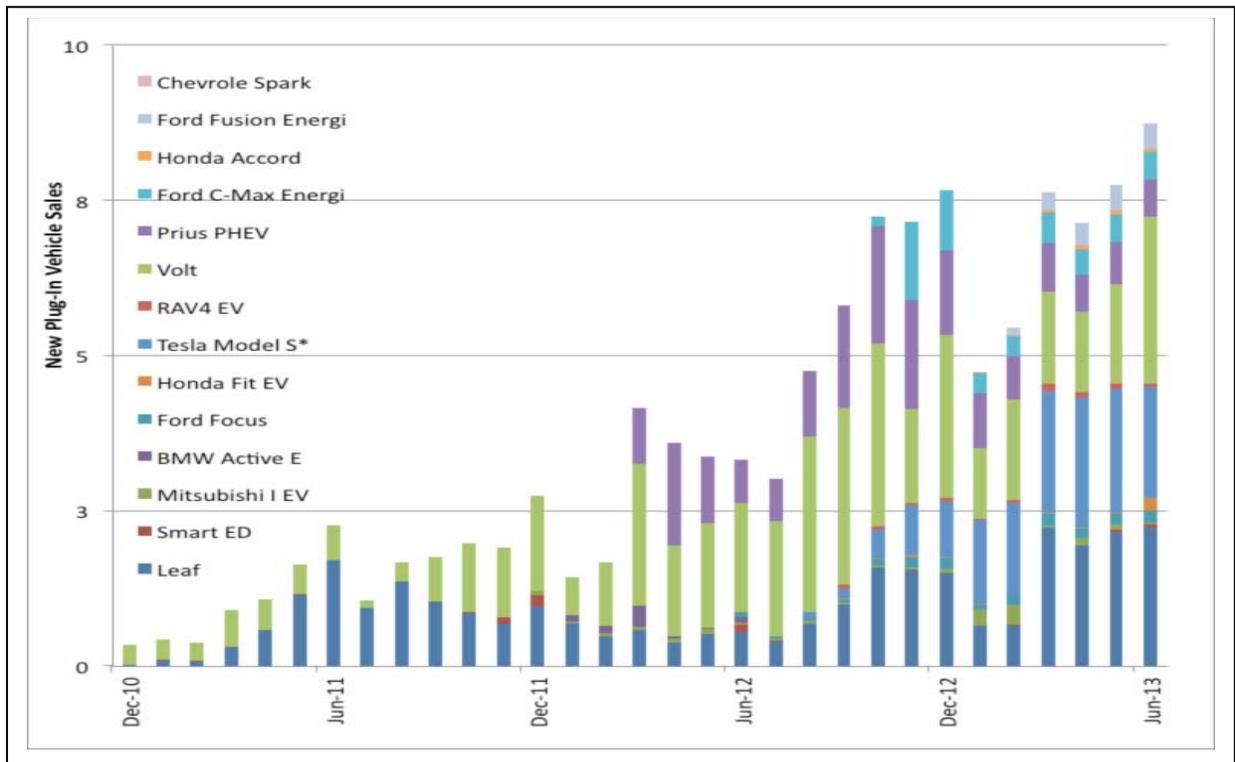


Figure 1. Number of electric vehicles (x1000) produced in U.S. from 2010-2013. [ANL]



Figure 2. Charging station with solar panels at the University of Iowa.



a. AeroVironment EVSE-RS+



b. Charge Point CT2021



c. Schneider Electric EV230PDRR



d. GE DuraStationNEMA3R

Figure 3. Typical commercial charging stations available. (Used with permission from AeroVironment, ChargePoint, Scheider, GE)

Table 1. Comparison of commercial charging stations.

	AeroVironment: EVSE-RS+	Charge Point: CT2021	Schneider Electric: EV230PDRR	GE: DuraStation
Price \$	5,600	5,745	3,299	5,445
Voltage VAC	240	240	240	240
Output Current A	30	30	30	30
Input Current A	40	40	40	40
Dimensions in DxWxH	12 x 12 x 42	15 x 12 x 56	6.7 x 13 x 56	13.8 x 14.9 x 51
Cord Length feet	25	18	18	20

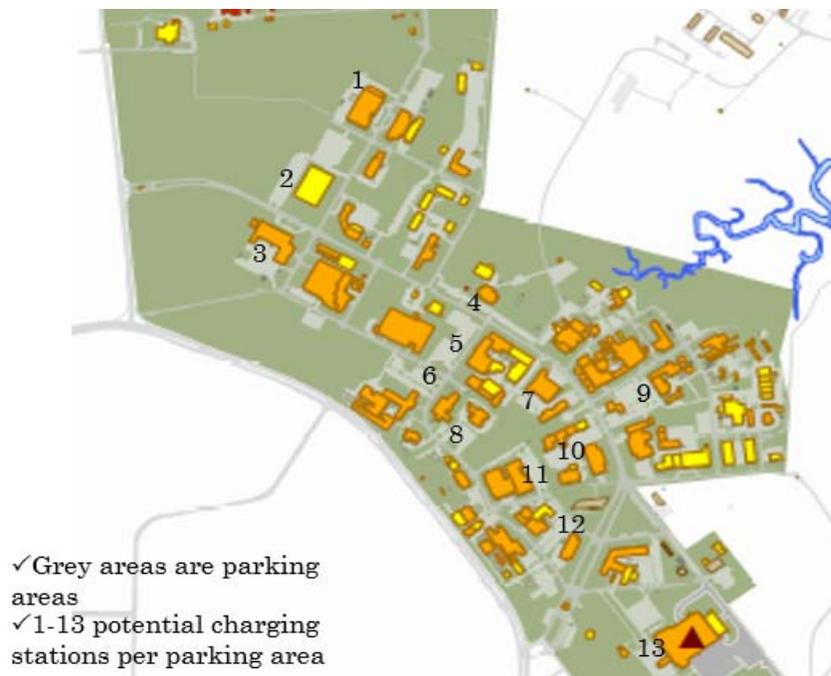


Figure 4. Map of NASA Langley Research Center with numbered parking lots.

Table 2. Long term plan for parking lots of NASA Langley Research Center, locations, number of parking spots in each and estimated number of charging stations per lot.

Map Number	Building	Parking Spaces	Charging Stations
1	1202	115	12
2	1209	440	44
3	1250	140	14
4	Reid Center	180	18
5	1268	330	33
6	1212	160	16
7	1219	96	10
8	1213	60	6
9	1247	200	20
10	1225	200	20
11	1148	150	15
12	1229	150	15
13	1244	240	24
14	1230	94	10



Figure 5. Close up of ChargePoint CT2021 screen. (Used with permission from ChargePoint)

Table 3. Total cost per dual station spread over 15 years.

Costs	Yearly Cost per Dual Station														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Station Infrastructure \$4500						450	450	450	450	450	450	450	450	450	450
8 Hour Electricity Usage	749	749	749	749	768	786	786	786	786	825	825	825	825	825	825
Installation (\$5000)	1000	1000	1000	1000	1000										
Maintenance/Replacement	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total \$ per year	1949	1949	1949	1949	1986	1436	1436	1436	1436	1475	1475	1475	1475	1475	1475
KwH User Charge \$	0.15	0.15	0.15	0.15	0.16	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

Table 4. Comparison of Level 1, 2 and 3 electric vehicle charging stations from *Charging While You Work: A guide for expanding electric vehicle infrastructure at the workplace.*

	Level 1	Level 2	Level 3 (fast charging)
<b>Power Supply</b>	120 V @ 12-20 amps	240 V @ 30-80 amps	up to 600 V (DC) or 480 V (AC) @ 100 amps
<b>Energy Use Characteristics</b>	1-1.5 kW/hr	3-7 kW/hr	75-100 kW/hr
<b>EV Range Boost</b>	2-5 miles/hr	8-20 miles/hr	60-80 miles (< 30 minutes)
<b>Bottom Line</b>	Widely available, low cost (\$10 to \$1000). Ideal solution to provide EV owners with more range, and to gain experience in workplace charging.	Widely available, moderate cost (\$500 to \$6000). Many 3rd party equipment and service providers. Ideal solution to provide EV owners substantial boost in range in less time.	Limited availability, high cost (>\$15,000 + installation). As of late 2012, this solution is not practical for most workplace charging sites.

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