Executive Summary

Portland's EV Future:
A Look at the Business, Technological, and Policy Potential for Electric Vehicle Adoption

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Introduction

The metropolitan region of Portland, Oregon has established a reputation as a green and progressive community, possessing strong environmental policies and motivated citizens. In the transportation sector, Portland has invested in an extensive public transportation system and boasts the highest per capita hybrid car ownership in the United States. It is, in part, this earned reputation that is now drawing automobile companies to introduce and showcase the newest generation of vehicles in the Portland metropolitan area, such as the Nissan Leaf, the first mass-produced electric vehicle (EV). EVs require an electric charging infrastructure, so, in support of the introduction of the EV, the EV Project is a widespread venture that will implement large-scale charging infrastructures in multiple communities. Of the 11 cities chosen for the EV Project, four are located in Oregon's I-5 corridor.

Oregon, among many states, has embraced the reality of climate change worsened by human produced greenhouse gases (GHG). Carbon dioxide emissions are a major component of GHGs. Multiple initiatives by Oregon's government, businesses and citizens are seeking to undertake change to decrease carbon emissions. Carbon reduction legislation and renewable portfolio standards for electricity production are promising steps towards these carbon reduction goals. Currently one-third of Oregon's GHG emissions are produced by the transportation sector. Therefore, a large-scale adoption of EVs presents a unique opportunity to potentially reduce the negative impacts of GHGs as well as many other toxic substances such as CO, NOx, SOx, particulate matter and ground level ozone.

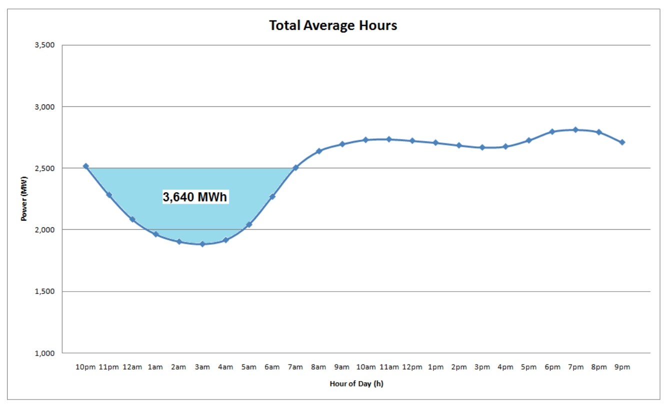
The introduction of EVs does not come without significant issues and challenges. Car battery technologies are far from being a mature technology. Current range limitations of EVs - roughly 100 miles compared to 300 for a conventional car - can cause "range anxiety." Charging infrastructure both inside and outside of the home is practically non-existent. Social equity concerns include the income gap for those who can and cannot afford the more expensive EVs and "garage orphans" who lack the capacity to install a home charging station such as apartment renters. Challenges for the electricity production sector are grid impacts, improper charging behavior, transmission, production, and peaking concerns.

Political agendas and regulations will undoubtedly play an important role in the future of the electric fleet; therefore, a solid vision of the future and sound policies to guide action are critical. Coupled with utilizing technological advances such as the Smart Grid and leveraging business opportunities, this forward thinking vision could create a favorable climate for the dissemination of EVs and also the environment.

Potential Utility Impact

One of the most widely used arguments against the introduction of EVs is that they use electricity produced from dirty sources in place of the traditional use of gasoline. The Pacific Northwest at least partly mitigates this issue due to the extensive hydroelectric sources of electricity that, after completion of the dams, do not directly produce GHGs or other toxics while generating electricity. In addition, wind generation in the Columbia Valley is growing rapidly, also producing clean energy. More importantly, however, the efficiency of an electric motor in an EV and the use of electric "fuel" have been calculated to yield approximately half of the amount of carbon dioxide compared to a gasoline powered car driven the same number of miles.[1]

Another concern of skeptics is that it will be necessary to build additional power plants to accommodate the increased demand on the power grid for electric car charging. The charging behavior of EV drivers plays an important role for this concern. For example, a car that is parked after work in the early evening and plugged in during the peak load for the grid is much less desirable timing than a car that is plugged into a charger that has a timer to start charging in the middle of the night. Time of use (TOU) or dynamic pricing capabilities are potentially powerful initiatives to incentivize EVs drivers to charge the car during off-peak hours. As an example, in this study, hourly usage data from PGE for 2008[2] was analyzed to determine the actual impact of EVs on the local utility grid. The figure to the right depicts the average hourly power load (in MW) for the entire year of 2008. The night time "trough" from 10pm to 7am shows that a potential leveling of the load could create 3,640MWh of electricity that would not otherwise be used. Assuming that the Nissan Leaf EV has a battery capacity of 24 kWh, nearly 152,000 electric cars could be *fully* charged at night during this trough period, using the average daily load shape.



A Portland Metro report (Daily VMT Per Person – 1990 to 2008) showed that the average Portland Metro driver commutes 19 miles per day, which is less than one quarter of the Nissan Leaf's range ability. Therefore, assuming that drivers perform no daytime charging, and that every single EV in Portland is charged every night, the existing grid could potentially accommodate well over 600,000 EVs. This analysis is quite promising when compared to a forecast produced in this study for three levels of EV adoption. The most aggressive growth of EV adoption estimates that by 2025 only 265,000 vehicles will be used. Thus, the Portland area could easily absorb an aggressive rollout of EVs if good charging practices are in place, including the use of TOU and dynamic pricing, as well as demand response. The worst case scenario in this study estimated that all owners would be charging at the average evening peak. Assuming a capacity of 10% over the average summer peak hour at 7 pm, and assuming a charging rate of 3.6kW (using a 240V and 15A charger), the grid could handle over 83,000 EVs all plugging in at 7pm. For perspective, the target forecast projected in this study would not reach this level until 2018.

It is important to note that Portland's commuters may exhibit shorter average commutes because of the urban growth boundary established by Metro, our regional government, and ample public transportation. Therefore, it is necessary for other cities to perform a similar analysis using local load shape and commuting ranges. There are other transmission and distribution concerns that are outside the scope of this study, but that are very important. Such examples are the capacity delivered to a cul-de-sac that has many EV chargers and peak hours when the grid is stressed such as during hot summer days when air conditioners are turned on. It is hoped that proper utility planning, good regulation standards, Smart Grid capabilities, and consumer education will aid in grid concerns.

Business Analysis

The business analysis was undertaken from the perspective of a triple bottom line: the social, environmental, and economic costs and benefits associated with EV adoption in Portland. Table 1 shows a qualitative list of each of the costs and benefits from the three perspectives. The qualitative assessment draws attention to some of the important concepts to consider when taking a holistic approach to cost benefit analysis. Though weighting or values were not assigned to each of these considerations, on a whole, the authors of this study believe that the benefits outweigh the costs from each of the three perspectives when looking at both short and long term impacts.

	Costs	**Benefits**
Social	Upfront vehicle cost Charging infrastructure Inequity *Cost burden/incentives* *Garage orphans*	Lower/stabilize daily travel costs Lower health care costs due to reduced urban air and water pollution Decreased noise pollution Reduce demand for oil
Environmental	Battery material mining and manufacturing Battery disposal Carbon and toxics from Boardman (until shut down)	Leveling of electricity generation such as wind firming Shifting pollution from gas to electricity *Cutting CO2 emission more than half* *Localization of pollutants (ozone, NOx, SOx, PM10, CO)* Human/ecological health Water quality Reduced material waste (tune ups)
Economic	Upfront vehicle cost Charging infrastructure Cost of poor charging behavior *Grid stress* Incentive costs Lost jobs in gas sector (minor)	Decreased urban pollution of CO2, NOx, SOx, CO, ozone Lower/stabilize daily travel costs Improve Portland's green image Help meet the Governor's carbon reduction goals Informed charging (flatten load) Green/skilled job creation Wind firming Increased electricity sales leads to more social services dollars Less foreign oil consumption for national benefit

Table1. Qualitative Assessment of Social, Environmental, and Economic Costs and Benefits

A final business consideration is the potential for local Portland businesses to expand or start new markets. New electric cars necessitate newly trained mechanics and charging station installers and technicians. There are also possibilities for parking garages or businesses to attract EV customers by offering parking spaces with quick chargers, while charging a profitable fee. Various billing methods for out of home charging could create an opportunity for a third party. And finally, home internet interfaces or mobile smart phones will undoubtedly provide charging status updates and other information. As with the advent of most new technologies, clever entrepreneurs will find new niches to create the “next” modern business model.

Technology Analysis

The main technological components for the EV system are the car battery; charging stations that provide either Level 1, 2, or 3 charging; and technologies enabled by the Smart Grid.

Batteries

Currently, lithium ion batteries have an expected life of 5-7 years, having made large technological strides since 2003, and are the front runner batteries for EVs. Lithium air batteries have a potential of ten times the wattage capacity compared to lithium ion but are in the development stage and not expected to be a viable option for another five years.

To prolong the life of lithium ion batteries they should be charged between 32° F and 113°F; this presents potential problems for charging of EVs in colder U.S. states such as those in the Midwest and East and in warmer states in the Southwest. Battery life can be extended by minimizing deep battery discharges and Level 3 charging. EV battery capacity is designed for range and to minimize the impact of discharging on battery life. EV in-vehicle battery chargers are designed to charge batteries in a manner that prolongs battery life.

Charging Stations

There are three categories of charging station based on voltage. The first level operates on a 120v circuit and charges a Nissan Leaf in 20 to 22 hours; the second level operates on a 240v circuit and charges a Nissan Leaf in 5 to 6 hours; and the third level operates on a 480v 3 phase circuit and charges a Nissan Leaf in 30 minutes. A Level 2 charge provides more energy to an EV than a Level 1 charger and a Level 3 charger provides more energy to an EV than a Level 3 charger. Level 1 and 2 charging is done by an onboard battery charger that connects to either 120v or 240v. Level 3 “fast” charging converts high voltage 3 phase AC current to high DC voltage and current which goes to a separate battery charger in the EV. Though international standards are still being formed for charging stations, it is certain that Level 3 chargers will have the same safety features as Levels 1 and 2. Software provides management and control of the charge rate to protect the charger itself and the vehicle.

Smart Grid Technologies

The Smart Grid will control the load on the grid from EVs to ensure that their collective load does not negatively impact the grid, i.e. cause brownouts or blackouts during periods of peak demand. Smart Grid technologies will allow utilities to control EV energy demand by financial incentives, such as time-of-use (TOU) and dynamic pricing, and by directly controlling the energy used by an EV through the use of demand response mechanisms including stopping and starting charging and controlling the rate of charging. Smart meters can enable TOU and dynamic pricing signals to automatically start charging the car's battery when a desired price of electricity is met. Demand response technologies allow the utility to send a signal to temporarily stop charging in the event of a potential strain on the system. Longer term, vehicle-to-grid (V2G) capabilities may provide a method for utilities to use an EV as "virtual" generator. Whenever an EV is connected to the grid, charging or not, its batteries could be used by the Utility for load control, peaking generation, and voltage and frequency regulation. Vehicle owners would receive payment by the utility for use of this power source, potentially at a premium rate. Networks such as Home Area Networks (HAN) and Field Are Networks (FAN) will be critical to implementing Smart Grid functionality. The Smart Energy Profile 2.0 (SEP2), the leading HAN standard, which is not yet approved, defines the interaction between a utility and an EV. It includes metering the energy consumed or supplied to the grid by an EV, which is key to implementing TOU and dynamic pricing, and V2G. Strong, robust and effective security is essential for the Smart Grid. It prevents someone from controlling and harming generation, substations and Smart Grid enabled devices in the home.

Policy Analysis

Social inequities are considerations for policy development of new technologies. For EVs, potential social inequities exist pertaining to the purchasing and charging of EVs. Currently, the federal government provides up to $7,500 in tax credits and Oregon provides $2,000 in tax credits. However, to benefit from the full credit of the federal incentive, a family must have a minimum income of $55,000 after deductions. The average Portland household pre-deduction income is $60,000. Assuming a standard deduction of $11,000, it is possible that a relatively large percentage of Portland households would not be eligible for the full federal tax credit. However, initial EVs will be most often used as second cars and households with higher incomes tend to house more workers and drive more miles per year. Therefore, these households represent the most promising market and EV adoption among higher income drivers will yield the greatest impact on environmental concerns and oil dependency.

A shift in the perception of how personal vehicles are used must take place before wide scale EV adoption can occur. Currently, most gas-powered vehicles have a range of over 300 miles. The Nissan Leaf has a 100 mile range which may cause "range anxiety" in some consumers. However, the average Portland commuter only drives 19 miles round trip per day. First generation EVs are not meant to be cross country vehicles, but instead to provide a reasonable solution to daily commuting needs. Public demonstrations, clinics, and public service announcements can be used to help ease the concerns associated with range anxiety by educating the public on how the driving range of initial EVs aligns with the needs of the average commuter. These educational forums would also provide an ideal venue to educate the public on the basics of owning an EV. Topics could include electrical grid basics; the impact of charging behavior on the electric power system; the use of timers, TOU and dynamic pricing, demand response; firming wind resources blowing at night; and the future of vehicle-to-grid (V2G). The most realistic short term solution to ensuring off-peak charging is to utilize timers on in-home charging stations so that the resident can physically plug in the car upon arriving home, with charging not beginning until a preset time, such as midnight. Education can better align the public's perception about the actual daily driving distance required and also inform advantageous charging behavior from the outset.

Challenges and Opportunities

The potential of EV adoption combined with Smart Grid capabilities could yield impressive results for Portland. From the above business, technology and policy analysis, three key areas have been identified that present potential challenges and opportunities for the widespread adoption of EVs.

Adverse Load Impact

If the EV market lacks proper consideration for potential grid impacts, poor charging habits could create large problems in the future. Instead of providing potential relief for the electric utility, a burden could form over time. To avoid burden on the grid, multiple steps could be taken. Education; Smart Grid capabilities such as timers, TOU and dynamic pricing and demand response; consistent regulation; and a forward thinking policy framework could provide protections and planning to safeguard against adverse grid conditions.

Smart Grid Technology Installation and Acceptance

To gain the full potential of EV adoption, the use of Smart Grid technologies must be maximized. Home and public charging stations, separate meters, and internet or phone connections must be installed by utilities, government agencies, or private companies. Codes and standards must be in place to ensure uniform installation practices and quality assurance.

Public acceptance is very important. After the early adopters, the general public will need to be educated on the fundamentals of the grid and pricing options. This upfront education and even the initial setting of default night charging could alleviate future burdens and include consumers on the evolving Smart Grid. Federal and state incentives will be necessary for several years to bridge the income gap. An alternative to tax credit could be an incentive pass-through from dealers, which would provide an immediate reduction in sticker price. Finally, marketing efforts should be undertaken to increase the visibility of electric vehicles and how best to use them. Advertising on websites, television, newspapers, movies, and other modes will accelerate adoption of these vehicles.

Policy Vision

The basis of a successful shift to EVs rests with sound policy. A policy *vision* is necessary because it implies a policy process that is ongoing and can be modified to keep current with technological advances in cars, charging, or Smart Grid capabilities. A uniform regulatory environment is key to ensure that EV needs are met. One such need is the quantity and location of charging stations that will help to guarantee that the Portland Metro area, and in the future the state of Oregon, is progressing at the same rate as other areas around the country. This will also help to ensure that opportunities are equal. A stimulation of utility investment can be achieved with sound policy to perform necessary grid upgrades to assure EV access. These kinds of utility expenditures must be considered prudent by the Public Utility Commission so that costs can be recovered through rates. Finally, state or city planning should incorporate EVs into Integrated Resource Plans to include forecasted geographic growth, estimate possible grid strain, and have plans in place to handle problems.

Electric vehicles are indeed coming to Portland. With the considerations outlined here, an informed and realistic discussion can be undertaken with respect to Portland's near and long term EV future.

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[1] DeCicco, John. "Can Coal Powered Cars Be Clean?" University of Michigan, School of Natural Resources and Environment. *http://www.hybridcars.com/environment/can-coal-powered-cars-be-clean-26233.html*

[2] Source: PGE FERC Form 714 Report