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Expanding the Fast Charging Network

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Oregon has more DC Fast Chargers (DCFC) for electric vehicles per capita than any other US region. This network has played a major role in making Oregon one of the strongest markets for electric vehicle sales in the US, despite the lack of a state purchase incentive. This paper summarizes Oregon's experience with fast charging, evaluates the impact of this network, proposes new ways of defining network "success," and makes recommendations for cost effectively expanding the network. These findings and recommendations should help inform other regions that are just beginning to build out their fast charging networks.

Keywords: fast charge, infrastructure, state government, policy, United States of America

1 Fast Charging in Oregon

Interstate 5 is the major freeway connection running over 2,000 km from the U.S. border with Canada, through Washington, Oregon, and California, to the U.S. border with Mexico. Oregon officials, working with other west coast jurisdictions through the Pacific Coast Collaborative[1], originally conceived the idea of the "West Coast Green Highway" (WCEH) stretching from Baja California to British Columbia as early as the 1990s, and focused specifically on the WCEH shortly after 2010. With creative use of recovery act funding and a USDOT TIGER grant, Oregon completed its portion by Summer 2015. The WCEH today is an extensive network of DC fast charging stations located every 40 to 80 km along Interstate 5 and other major roadways in the Pacific Northwest.[2] These stations have also been branded with a common logo and "look and feel," providing greater visibility and driver confidence. (See Figure 1.)

Figure 1. Author using a West Coast Electric Highway charger

As outlined in Figure 2, this network now covers most of the region's major transportation corridors. California recently provided funding for installations between Ashland, Oregon and Sacramento, which will close the last gap in this charging corridor.[3]

Figure 2. West Coast Electric Highway Map

Oregon was also a participant in the EV Project, and the major Willamette Valley cities of Portland, Salem, Corvallis, and Eugene were all included (See Figure 3 below.) The Idaho National Laboratory has developed extensive fact sheets, technical reports, and presentations summarizing the results of this project.[4] After the bankruptcy of Ecotality, Car Charging Group now operates the charging stations built through the Project.[5]

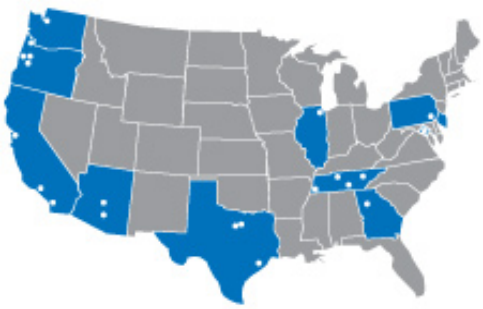

Figure 3. EV Project Locations[6]

Oregon has also been a leader in providing fast charging in the urban core via its "Electric Avenue" project. Electric Avenue was launched in 2011 as a test bed for vehicle charging equipment. Electric Avenue solicited charging equipment from several different companies and placed it side by side to evaluate its

technical characteristics, its reliability in use, and the consumer experience of charging. This deployment yielded many lessons about technology and the user experience, which have been summarized elsewhere.[7] This charging oasis had to be relocated due to construction at Portland State University, and was re-created at Portland General Electric's downtown Portland headquarters in 2015. (See Figure 4)

Figure 4. Electric Avenue "2.0" in Downtown Portland

As a result of these coordinated efforts, Oregon now has the most robust state-wide network of DC Fast Chargers in the nation, with about 120 stations in operation and more being added monthly, to serve a population of 4 million and a fleet of over 9,000 electric cars. This network now covers most of the region's major transportation corridors.

2 Defining "Success"

Measuring "success" in building the DCFC network is not simple.[8] Some analysts have focused on the number of charging sessions per day or per week. By that measure, very few fast charging locations are "successful" or profitable so far – which has prompted many negative media stories about money that was "wasted" building out charging stations. However, this is a grossly simplistic measure of success, akin to measuring the 'success' of your house's wiring by measuring how often you had something plugged into each outlet. The truth is you want an outlet conveniently located wherever you may need it, even if you don't use it very often. The same is true with a vehicle charging network. Ultimately, the number of uses per day will be one significant financial driver – but it's grossly inadequate as the sole or primary measure of success, particularly in these early years of the market.

One key measure of success is access: simply put, the degree to which drivers can travel the state, going about their regular business, without worrying about their ability to charge. This is the rationale that leads public agencies to provide rest areas, street lighting, sidewalks, electricity to rural homes, and other basic infrastructure. This was the approach taken in Oregon: create enough "stepping stones" so that EV drivers could travel major corridors and reach popular travel destinations around the state.[9] Many locations are absolutely necessary to get to popular destinations, such as the coast, but are unlikely to have heavy use for many years. Oregonians can now readily travel by electric vehicle to the coast, between our major cities, and to many popular destinations. In fact, Oregon has built on this network to develop one of the world's first and largest EV Tourism programs, including the first fast charger at a ski resort[10], statewide Electric Byways[11], and a "Plug In and Pinot" wine country tour.[12]

Another measure of success is whether the DCFC network provides a foundation of consumer confidence that drives increasing sales of electric vehicles and an increasing number of electric vehicle miles travelled (e-VMT.) Oregon has committed to accelerate sales of electric vehicles by opting in to the Zero Emission Vehicle (ZEV) mandate, and has also joined the International ZEV Alliance, committing to a goal that all new cars sold in Oregon will be electric by 2050. Oregon must get from just over 9,000 registered electric vehicles today to about 130,000 cars by 2025 to meet the ZEV mandate; to meet its global warming goals it must reach 300,000 cars by 2020 and over 1.5 million electric cars by 2050. Since Oregon only sells about

130,000 new cars per year, these goals require sales ramping up to between 15% and 50% of new car sales very quickly. This creates a responsibility for the state to also ensure the fundamental conditions that encourage and support electric vehicle sales and use. Evidence from the EV project does suggest that DCFC does lead to more e-VMT, and anecdotal evidence certainly suggests that ready availability of DCFC increases drivers' confidence and willingness to buy electric vehicles. However, this is an area that is also ripe for further quantitative research.

Third, and lastly, should come charging usage. Ultimately, if DCFC is going to pay for itself through fees for the use of chargers there must be enough charging activity to provide a financial return to the system operator. While there are many variables, one rough 'rule of thumb' is that a DCFC needs to be used at least 10 times per day to break even. The chargers on Oregon's West Coast Electric Highway are used far less often – from a high of ~5 uses per day to a low of ~1 use per month in some locations and some months.[13] While chargers on Portland's Electric Avenue downtown are more heavily used, they are currently free of charge, which makes direct comparisons difficult. Overall, it is not at all clear that DCFC can, or should, pay for themselves simply through usage fees in the next few years.

3 Next Steps for Oregon

Although Oregon has an extremely robust fast charging network compared to other regions, we believe it will need to be dramatically expanded to support the state's goals for electric vehicle deployment over the coming years. Stakeholders in Oregon recommend the following specific next steps in expanding and improving the DCFC network.

3.1 Densify the network in metro areas

Drivers don't just use DCFC for long trips between cities. They use this equipment to travel across metropolitan areas in a single day, as a "safety net" for unexpected trips during the day, and as an option for drivers without home garages or workplace charging. These chargers should installed in highly visible groupings with multiple DCFC and L2 chargers, modelled on Portland's Electric Avenue project, to maximize marketing value and minimize the waiting time for drivers queuing to use stations.

3.2 Add SAE combo to key corridors

When the WCEH was constructed, only CHAdeMO vehicles were available. Now that increasing numbers of manufacturers are selling vehicles with SAE Combo DCFC capability, we should ensure that they can also travel freely. Ideally, these should be new chargers co-located with existing WCEH chargers, in order to also help alleviate congestion issues.

3.3 Ensure that key destinations outside metro areas are within reach

Experience shows that drivers are not simply using electric cars as urban runabouts. They want to be able to drive on electricity to the coast, to the mountains, etc. Some of these routes have long stretches where three-phase power is not available. Battery backup systems or single phase DCFC will be needed in these locations, possibly increasing installation costs. These locations will also be the least likely to "pencil" based strictly on usage payments – but just as we extended electricity to rural homes to create universal access, we need to move toward ensuring universal access for EV drivers as well.

4 Lessons Learned and Recommendations

Based on Oregon's experience as an early test bed for fast charging technology, we believe a number of clear lessons have emerged that can help other regions now looking to develop and expand fast charging corridors and networks. These recommendations are targeted especially at public policy makers and planners, but we hope they are also helpful to private network developers and automotive planners as well. Private companies may place DCFC where they wish, but for the public to put time, effort, and scarce resources into providing DCFC, we need to be as efficient and strategic as possible. It's important to note that this paper sets aside the rather unique, vertically integrated Tesla Supercharger network.

4.1 Fast Charging Corridors are Great Marketing

As Oregon has seen, installing an initial "backbone" of DCFC along key travel corridors can generate positive media stories, and send a strong message to drivers that "you can drive all the way across the state in your electric car." This kind of messaging helps inspire driver confidence and sales. In this regard, Section 1413 of the FAST ACT, which requires designation of Alternative Fuel corridors along major highways by December 2016, is very constructive.[14] Investments by major automakers to help build out fast charging corridors, such as the partnership between BMW, VW, and ChargePoint, are also very helpful.[15]

However, in practice and with current vehicle technology, only exceptionally dedicated drivers are going to make trips of over 150 km by electric vehicle. Rather, drivers will tend to make slightly longer trips, using one or two fast chargers to enable an "out and back" trip or a slightly longer journey. Drivers should be able to access key destinations by electric vehicle, but planners and policymakers should not be drawn into thinking of long distance DCFC corridors too literally. With the emergence of 300+ km cars like the Chevy Bolt, and faster DCFC protocols, longer trips should certainly become more common and feasible – but for now, trips of 100-150 km are going to be much more common.

4.2 However: Focus First Where the Drivers Are

All electric vehicle drivers benefit from fast charging, not just those contemplating long trips between cities. Drivers use this equipment to travel across large metropolitan areas in a single day, as a "safety net" for unexpected trips during the day, and as an option for "garage orphans" without home or workplace charging options. In fact, some drivers simply prefer the certainty and convenience of fast charging even when level 2 charging is also widely available. Planners should ensure that fast charging is readily available where electric vehicles and their drivers are already located, and where sales are expected to be highest in the next few years.

These chargers should be installed in extremely high visibility locations to maximize their marketing value. They should also be placed where drivers have easy access – in urban areas, ideally in the public right of way or on the street level. Nearby amenities are helpful, though in practice, many drivers are likely to check email or talk on the phone, remaining in their car for 20 minutes while charging. Furthermore, as noted below, these chargers should be installed in pods or hubs with multiple DCFC and L2 chargers to increase visibility and usability.

For this reason, too, even when corridor chargers are being installed, they should generally not be located directly on the highway or in a "rest area" model. They certainly need to be fairly close to the highway, but they should also be located where regional drivers can readily access them, and where amenities (snacks, bathrooms, Wi-Fi, etc.) are readily available. This will maximize their value as both "corridor" chargers and "regional" chargers, maximize their use, and help ensure that they maximize both revenue generation and electric vehicle sales.

Rest areas on Oregon's freeways give away free coffee to motorists – but only those who are truly in need will stop to take advantage of the offer. By contrast, Oregonians will line up to pay for coffee at one of our "destination roasters." By the same token, fast charging installations should strive to be preferred destinations and charging locations of choice – not chargers of last resort for the desperate.

4.3 Fast Chargers Must be Completely Reliable

Wherever they are located, fast chargers are critical infrastructure for electric vehicle drivers – much like gas stations are in remote rural communities. Fast chargers must be exceptionally reliable, and should measure downtime in terms of minutes per year, rather than days – similar to utility reliability measures. This is a significant challenge for public infrastructure with substantial electronics. After some initial hiccups, currently available fast chargers seem to be up to the challenge – but as pressure grows for these machines to get cheaper and faster, we need to be vigilant to insure they remain reliable as well.

Beyond engineering reliability, however, fast charging installations should also be resistant to business troubles or the vagaries of site hosts. Oregon experienced a major scare when Ecotality declared bankruptcy. If its Blink fast chargers had gone 'dark' the state's electric vehicle drivers would have been in serious trouble. Similarly, the current fast charging network in Oregon relies heavily on AeroVironment, the company that installed the West Coast Electric Highway and operates it under contract. When that contract ends in a few years, it is not clear what may become of this network. One of the best ways to make

the system more resilient is to require or incentivize systems that do not rely on proprietary software networks, but rather use open source software and communications such as the Open Charge Point Protocol.[16] This will help ensure that a new operator can step in to operate a charging network, and that site hosts can switch network providers, without having to replace expensive hardware.

4.4 Install Chargers in "Pods"

Because Oregon was operating with a very constrained budget, and wanted to create as long a corridor as possible, the state initially installed just one charger at each location. However, this means that if the fast charger is down for some reason, there is limited backup (although each location also has a Level 2 charger, this is a poor substitute for a driver on a schedule.) Furthermore, as some charging locations become more popular, having just one charger inevitably leads to queuing problems and waits. Basic queuing theory suggests that having two or three chargers will dramatically reduce the likelihood of a driver having to wait. Therefore, chargers should be installed in larger clusters or "pods" wherever possible.

Another reason for the "pod" approach to charging has become clear at Electric Avenue. Electric Avenue hosts four dual standard DC fast chargers as well as two level 2 chargers in a highly visible on street location. Electric Avenue has emerged as a major magnet for public charging, as drivers know they are always likely to find an open fast charger. It has also become a major focus for broader electric vehicle activity, from meetings of the Oregon Electric Vehicle Association of drivers and enthusiasts to launches of new car models. This approach will also help facilitate use of electric vehicles in car-sharing systems, such as BMW's ReachNow service, by providing an easy place to drop off and rent vehicles. Just as Portland's food cart pods have become popular destinations for diners, fast charging pods will become popular destinations for EV drivers.

While this "pod" approach is ideal from a driver's point of view, demand charges (discussed below) and other factors can be barriers. If it is only possible to install a single DCFC, planners should at least aim to include a secondary Level 2 charger.

4.5 Deal With Demand Charges

Utilities impose demand charges based on the peak power used during a billing cycle, regardless of how much energy is drawn at that rate. These charges are triggered by maximum power draw, not total energy use, and are not cumulative. They are designed in part to allocate system upgrade costs to specific high-power energy uses.

As many other authors have noted, utility demand charges can be a major barrier to widespread fast charging availability.[17] The West Coast Electric Highway, for example, includes chargers in 21 different utility service territories in Oregon and Washington. Demand charges at these virtually identical installations range from zero to over $350 monthly, or from zero to over $7/kW, leading to effective costs per kWh dispensed ranging from 5 cents all the way to 33 cents. Demand charges in other utility service territories around the country can be much, much higher, and can constitute 80-90% of a location's power bill.[18] Obviously, demand charges have a much larger impact at installations that are used only infrequently. If a fast charger is only used a few times per day – or per month – demand charges are virtually impossible to recover from drivers. At least one fast charger in Oregon has been "cranked down" to 30 kW to avoid demand charges, resulting in reduced service to drivers.

There are a number of strategies to address demand charges for fast chargers. Some utilities simply waive them as a matter of policy. Others, such as Portland General Electric, offer a slightly higher time of use rate for chargers that waives fixed demand charges.[19] Adding energy storage to buffer the initial power draw, or using smart energy management software, can also reduce peak loads. Whatever combination of technology, policy, and pricing strategy is used, however, it is important that planners address this issue early and directly - before widespread fast charging is installed.

4.6 Make Chargers Dual Standard

The West Coast Electric Highway was originally built only with CHAdeMO chargers, because only CHAdeMO vehicles were available. Now that increasing numbers of manufacturers are selling vehicles with SAE Combo DCFC capability, Oregon needs to overlay the network with SAE chargers. Other regions should ensure that fast charging installations are always dual-standard from the beginning (with the possible exceptions of automotive dealerships or similarly proprietary locations.) Several manufacturers

make single units with dual cords, which lowers the cost of dual-standard charging even further. In locations, such as Oregon, where CHAdeMO chargers are working well, it may be best to add a second charging unit with SAE or dual cord sets to also reduce congestion. The availability of converters also makes these stations available to Tesla drivers as well.

4.7 Cooperate and Co-locate

Increasingly, the greatest expense to installing DCFC is not the charging unit itself, but the power and installation costs. Planners should work closely with utilities to select suitable locations that also have nearby power, but co-location of chargers can also dramatically lower costs. For example, at least one site in Oregon houses both Tesla Superchargers and a West Coast Electric Highway charging installation. Coordination, co-location, and pooling of resources from multiple sources (vehicle OEMs, EVSE providers, site hosts, government agencies, etc.) will dramatically lower costs. Cooperation and co-location also improves the driver experience, making chargers easier to find and increasing the likelihood of finding and open charging unit.

4.8 Ensure an Excellent Driver Experience

Fast charging should be an easy, pleasant, convenient experience that gives drivers confidence to make longer trips and drive more electric miles. The first step in this process is ensuring that DCFC stations are easy to locate. As part of Oregon's work on the West Coast Electric Highway, Oregon developed consistent signage to direct drivers to EV charging stations along the freeway and placed these signs alongside existing "gas-food-lodging" signage. This signage (Figure 5) has since been granted interim approval by the Federal Highway Administration for nationwide use.[20]

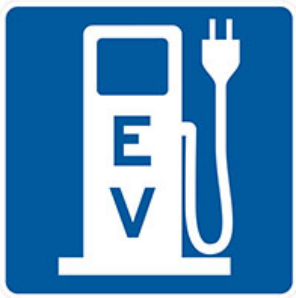

Figure 5. EV charging sign

Most EV drivers find charging stations using in-vehicle telematics or software applications such as Plugshare, Blink, or ChargePoint. However, highly visible freeway signage serves the dual purpose of helping EV drivers while also sending a marketing message to potential future EV drivers.

Once off the freeway at the charger, there needs to be an easy way for drivers to use the charger without having to carry a proprietary key fob or card. Again, these systems are being rapidly developed. Over time, we look forward to these systems being expanded and upgraded with features like the ability to reserve charging sessions.

4.9 Develop Creative Solutions for Remote Locations

Much of the United States, particularly in rural areas, does not have 480-volt 3-Phase power installed, creating a need for fast charging solutions that do not require it. At least one company, EV4 Oregon, currently provides a battery-driven fast charger that meets this need[21], and other products with integrated storage are in development. Another potential solution in some applications could be a slightly slower (25 kW or less) fast charger.

4.10 Plan for More and Faster Charging

Drivers are impatient, and are accustomed to instant gratification. Drivers will continue to push for a faster charging experience – and even as vehicle batteries get larger, and vehicles get greater ranges, drivers will be reluctant to wait beyond the 20-30 minutes they are currently waiting to charge. Therefore, planners should expect that overall demand for fast charging will continue to increase significantly, and that "fast" will need to get faster. Audi has already announced plans for a nationwide 150 kW fast charging network by 2018[22], and CHAdeMO has announced plans to roll out 150 kW fast chargers by 2017.[23] The future is likely to include a lot more fast charging – at a much higher level – for many years to come.

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