Electric Vehicle Supply Equipment (EVSE) as a Product – An Investigation into Intelligent Product Packaging

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Searching for the Proper Package for Electric Vehicle Supply Equipment (EVSE)

It takes just two minutes and thirty seconds to render a typical Electric Vehicle (EV) Direct Current Fast Charger (DCFC) site inoperable (Krisher, 2024). How? All it takes is a car and cable cutters. Cable theft has been a growing issue accompanying the growth in EV infrastructure. Electrify America is just one of the many EVSE providers and reported that over the past two years they have observed a growth in cable thefts among their ~4,000 chargers from one every six months to around 129 (ScrapWare, 2024). Without a charging cable, or even damaged cables, EV chargers are unable to provide any meaningful service to EV drivers and thus can cause disruption to day-to-day functions. A lack of security features is just one part of a larger failing of EVSE design that is contributing to the division in consumer experience. Very often we are caught up in the naïve perspective that in order to promote conversion from the internal combustion engine to electric drive we simply need more chargers. To some extent this is true, but we must remain cognizant that technology itself is a shaper of society. Langdon Winner in *Do Artifacts Have Politics?* emphasizes that technology has a capacity to impose upon society certain norms or experiences (Winner, 1980).

Technology as a Shaper of Society

I will explain, briefly, the relationship between technology and society to help ground the importance of addressing EVSE at the user experience level. Science, Technology, and Society (STS) promotes a perspective of products, devices, and technologies as integral, acting parts of the world we live in. The car is not just a mode of transportation, it is a way of living. The proliferation of cars and personal transport has cemented society into car-centric urban design. Cities are built for cars, not people. These spaces are not welcoming to those of lower income or

those who have physical impairment and cannot operate traditional cars (Kay, 2013). This interaction between technological products and society shows that in many ways our choices to offer certain products and in what form have serious consequences. When we acknowledge and act upon the capacity of accommodating designs, we empower ourselves to produce a more sustainable future. This paper aims to take this relationship between technology and people to help research a plan for developing more equitable EVSE formfactors, the "kiosk" drivers drive to pay and access the charging cable.

Methods

EVSE Under Lense of Feminist Technoscience

I used the Feminist Technoscience framework to analyze my topic. Feminist Technoscience is interested in how power dynamics contribute to isolating marginalized groups from developing technology. This is incredibly important in the context of this paper, which acknowledges that there are particular demographics who most strongly feel the deficiencies in contemporary EVSE design. Women, the physically impaired, the elderly, and the lower income are all examples of peoples who would be at a power disadvantage and thus are prone to being disregarded in the early stages of an emerging technology like EVSE.

The source of these deficiencies is a lack of perspective. It is hard to separate the designer from themselves. That is to say, a field dominated by white men (90% male, 63% white) is going to inherently be biased toward their own capabilities and needs. It is essential to counterbalance this by investigating the needs and concerns of marginalized groups in respect to EVSE. Once these have been identified, we can put together a strategy for how these deficiencies can realistically be met.

Source Finding Strategy

Sources provide background into the issues/concerns of current consumers, engineering design reasons, and what features are being pushed by involved parties. Key words and phrases used during research were “EVSE User Experience”, “EV Charging Standards Survey”, “EV Charging Cable Theft”, “EVSE Security Concerns”, and “EVSE Confusion”. To address the issues/concerns of consumers, a key type of source is forum posts. Typically, forum posts are not heavily filtered and are a common medium for individuals who have developed strong opinions about a topic. These forums were found on Google, including Reddit and automotive group forums like SpeakEV. Reports from professional groups like consumer reports play another important part in the picture, in general offering the experience of more knowledgeable individuals. This is a “double-edged-sword” as the added experience allows for more specific, precise comments at the expense of representing the majority of potential consumers (whom have had no experience using public EVSE). Also, professional studies and surveys that ask participants about their experience or put the participants into a controlled experience were used to complete the picture regarding how EVSE designs do not accommodate consumers. For design considerations, I used articles from journalists and releases from EVSE vendors/manufacturers (manuals and technical specifications/datasheets). These resources are not infallible, given that they could be worded in misleading ways to promote the company image. However, these documents are still worth considering as long as precautions are taken, like finding corroborating sources. Finding what features relevant parties are pushing is somewhat related/overlapping with the prior source types. In official adverts and newsletters by vendors/manufacturers one can often find features that make the experience unique, or at least in the eyes of the company. A good example would include “plug-and-charge” technology for

contactless payment, which was a large selling point of Tesla's charging network. There is also a lot of information in government policies/recommendations. Governments like those of the U.S. and U.K. have investigated the circumstances of EV charging and released recommendations or even enacted laws to move EV charging in a particular way. Whether these directions are good or bad is a question this paper hopes to address and use to shape a cohesive plan for EVSE growth.

Results

Concerns with Safety

One major category of consumer opinions was the idea that contemporary EVSE are unsafe, regarding the physical safety of the user as well as financial/digital safety. A Reddit post by user Branchop introduces an unsuspecting concern for users. Branchop expressed that during her charging experience at night she felt insecure due to the necessity of having to look at her phone for an extended period of time to interact with the dispenser rather than being aware of her surroundings. Another user, Regular-Wolf-9809 contributes to the conversation by noting, "Most of the chargers are very tall and provide minimum lighting during your sessions at night" (Branchop, 2023). To summarize the Reddit thread, there are many common features, or lack thereof, that either distract or create physical barriers to visibility. What turns these concerns into problems is a mix of the environment and power dynamics. Simply being vulnerable in terms of physical capacity (stereotypically women but also men who may do not fit into the gender normative masculine role) is not necessarily going to make you feel insecure at a charging station. It is reliant on distrust about the community and/or immediate surroundings. That is to say, to make a lack of attention a safety concern there must be a threat. For the psychological effect, there just needs to be a sense of threat or perceived probability of a threat being present.

On the financial/digital side, the increasing technological integration of EV charging systems leaves much to be desired in terms of security. Most every charge point operator (CPO), the company servicing the EVSE, relies on constant communication between car and dispenser and dispenser and backend, the server-side infrastructure processing the transaction and billing. And while this is not necessarily a problem, as similar information already is transferred for credit card transactions at the gas station, the complexity of EV systems means there are simply more points of failure where a third-party can enter the network maliciously.

Another concept relating to safety is the idea that the design of EVSE lend themselves to disruption of day-to-day life due to a lack of security. Take for example the idea presented in the introduction, that charging cables are currently completely unprotected to simple cable cutters. This renders the dispenser useless for an extended period of time (between the time the customer reports the issue, a technician inspects the dispenser, parts are ordered, and finally the technician repairs the dispenser). And with how little time it takes to cut off the cable, as the article claimed about two and a half minutes for a small-sized station, this might cut a whole community off of charging. Furthermore, this will disproportionately affect individuals with lower incomes. The reliance of public EVSE heavily leans toward lower income individuals since the more well-off often have single-family homes with the capability to charge at night. Compounding with this is a concern for the general security measures to keep individuals out of the power equipment. Akin to common concerns with sub-stations for the power grid, an individual with enough determination can easily damage power equipment with the most common dispenser configuration in the U.S., a distributed power-cabinet and dispenser. The power-cabinets that take AC off the grid and distribute it to dispensers are stored together in one fenced off location

at the charging site. Additionally, little attention is given to protecting power cabinets, amounting to usually thin fencing with a single lock.

Confusing Instructions

In a study by Haopeng Wu and Wonseok Yang, "The experimental setup featured a simulated EV charging station interface, where participants completed tasks mirroring real-life scenarios." (Wu, 2024, Page 1). Wu and Yang's study is directly investigating the barriers created by user interface design and found that education and language both acted as major barriers to understanding how to use the dispenser (not being able to make sense of the sparce instructions). The feedback from the participants directly addresses issues with the text format making it hard to read, terms being unfamiliar, and/or the density of content making it inviting of disengagement. This follows a similar vein as the information presented in the VICE article *Electrify America Just Made Electric-Vehicle Charging a Lot More Confusing* by Aaron Gordon. This VICE article follows the move from Electrify America, an EVSE company, to change the traditional numerically distinguished charging limits to descriptors. The article covers not only the confusion of terms like "hyper" and "ultra" but further explains the general disconnect of the public with how EV charging works. There are those who know and those who don't. Without any background in physics, one can find it difficult to make sense of what is happening, like why the charge rate is not always the number on the dispenser. This can be used to draw a divide on the premise of educational background, which to some extent is tied to socioeconomic standing. Age also will play into the discrepancy, since what is "common knowledge" through the public school system have changed significantly over the last 50 years.

Compatibility Issues

David Rempel found that a staggering 27.5% of charging sessions were not able to successfully initiate charging. The reasons why varied greatly between the EVSE manufacturers. “Cable would not reach”, for example, plagued 7.1% of attempted charging sessions at Electrify America dispensers while only 1.9% at EVgo. This problem is put into perspective by the experience of Reddit user mgdwreck who notes that the lack of cable length on the Tesla charger forced him to pull up to an uncomfortable distance to the curb. The problems at a societal level arise due to the ties between automakers and certain demographics. At the extreme we have the example of a typical Ferrari driver versus a Ford driver. Certain socioeconomic demographics will frequent certain manufacturers because they fulfill different market segments. As we try to standardize an EVSE design we must do it in a way that does not exclude products of a particular automaker, as we know that it will indirectly isolate whole demographics.

Poor Ergonomics

John Hekman’s *Electric Vehicle Charging Infrastructure for People Living with Disabilities* explores the difficulties experienced by those with disabilities in using EVs (Hekman, 2020). Charging cables have to be quite heavy due to the nature of more copper being required to support higher charging currents and thicker insulators to protect the user from high voltage. The cables end up being significantly heavier and stiffer than their gasoline counterpart to the point where it is a legitimate concern that the elderly or other demographics that typically have limited carrying capacity. This problem can be made worse by the charging standard. The three most common type of charging standards are the North American Charging Standard (NACS), the Combined Charging System (CCS), and Charge de Move (CHAdeMO). These chargers vary greatly in size. This translates to weight and bulkiness, which again does not help

with the user manipulating the cable to connect it to their vehicle charging port. This ability to manipulate the cable precisely is quite important and sensitive for EV charging, as electrical contacts need to be well seated and locking mechanisms need to engage to allow for charging (implemented to mitigate the prior concern of poor electrical contacts and accidental disconnects). Reddit user mgdwreck, who commented on the prior topic of compatibility concerns, also mentions this as a problem with his experience. He specifically speaks to the experience of his adapter locking mechanism not working for two of the three dispensers he tried to charge at during that day. The elderly, physically impaired, and women are all demographics who may see significant impact from increased rigor of use. Even if they can perform the task, discomfort in performing it can be a serious barrier to continued inclusion in EVs and EVSE.

What are Consumers Looking For?

There was also a J.D. Power evaluation of EVSE experience, and it found a major consumer interest was in "Plug & Pay" (Effler, 2024). This feature reduces the interaction between consumer and dispenser, streamlining the process.

EmilyA from EvSpeak wrote about their struggles with EVSEs on their latest road trip. They talked about many UX issues including the human-machine interface (HMI), payment, and charging cable configuration. Lack of shading was a standout topic from EmilyA's post. A lack of shading affects the usability in that the user cannot see the HMI and meant the HMI could easily become wet. Although water does not always mean catastrophic failure, the water can affect the touch screen sensitivity and the visibility of the screen (think of a car window with no windshield wipers).

Design Considerations for Charging Standards

Design is a very complex game of balancing interests. Here I will describe some of the important perspectives driving EVSE designs right now. At the corporate level, a lot of incentives for a successful EVSE design are built around satisfying coverage and minimizing costs. One might see these affecting the quality of the product as reducing quality control or using cheaper parts does allow the company to build more sites and chargers. This is also seen in the implementation of power sharing, which is to say you can use a power setup that has a maximum output below the total maximum output of all of the dispensers at the site. This is done by sharing power. For example, if a client uses one of two dispensers it can provide the full rated power of 350kW. When the second dispenser becomes occupied, the first one derates to split whatever the maximum of the shared power-cabinet is between the two, 175kW for each if the power-cabinet was rated for 350kW. This style of power distribution is essentially a locked decision from the perspective of most companies since implementing a change would mean two different architectures have to be supported simultaneously unless they choose the very costly path of completely refitting old charging sites.

An engineer typically views things from a standpoint of efficiency. The system is packaged densely, is safe, and is energetically efficient. Therefore, they may view this common, contemporary setup as suboptimal. If a combined power-cabinet and dispenser could be achieved, it would be easier to distribute power and the overall system would be more efficient. This is because the combined system keeps cable lengths to a minimum, mitigating loss of energy through the resistance of the cable. This also means less work needs to be performed to install the EVSE. Rather than building out a section to host the power cabinets then planning for

the cabling and then the dispenser, a combined system only has to plan cabling from the grid straight to each unit.

Technicians care about simplification of the maintenance process. They want to be able to perform their job quickly, which is made possible by a reduction in parts, assistive features, space, etc. We can already see a conflict in interest here with an engineer. A technician wants space in the unit to manipulate screws and wires, but this would cause the packaging density to decrease. There would be more volume unoccupied by equipment. Likewise, adding part labels and instructions require a flat, empty surface area to be made.

One other thing which is worthwhile mentioning is the technical reasons for each of the popular charging standards. NACS is very compact. By combining the AC and DC circuitry together, the effective packaging can use less parts and take up a smaller volume. CCS uses a split system with dedicated DC pins and AC pins. This is safer, since there is no chance of injecting the wrong type into the vehicle, but it also means more copper, pins, and size. CHAdeMO takes this one step further by eliminating the AC pins completely. For public EVSE this is desirable since DC is the objectively more efficient mode of energy transfer when going from dispenser to vehicle. However, it means a separate port and cable would be required for lower power home charging, specifically from AC outlets standard on modern houses.

Discussion

There is a lot to digest from the Results section, so I will approach this a piece-meal fashion. First and foremost, it is too late for the U.S. market to change to a combined power-cabinet and dispenser setup. The cost to revamp current infrastructure, which is already lacking,

would likely cause failure for EVs as a whole. Trying to make the most out of distributed power distribution is the best option for the U.S.

The problem of poor visibility can be addressed through mitigating dependence on lengthy processes and physical obstructions. Mobile payment is not inherently bad, but it should not be the only option available to the customer. The same goes for plug-and-charge technologies too, like Tesla's system. Although plug-and-charge is a highly desirable feature and a potentially simpler payment method for the less tech-acclimated, it still lacks compatibility with older vehicles. Cars built before the widespread use of plug-and-charge will remain on the roads if not with their original owners, then with second-hand owners. These cars still need to charge. Furthermore, whole generations grew up on credit card payments and may prefer it as the payment method. This leads to the conclusion that a variety of payment options need to be available. A lot of chargers on the market do offer this variety, like Electrify America and EvGO both accepting credit card and payment by app/web.

To make these payment methods effective, improvement must be made to the instructions provided. This was an important takeaway from the Results section, where studies show that common frustration comes from the complexity of the instructions. If instructions can be streamlined, the user will spend less time with their focus away from their surroundings, dually addressing the concern of safety. Pictures could be useful to reduce the amount of text but also give a sense of direction avoiding language barriers (including jargon).

In terms of the physical visual barriers, a Tesla styled approach might be useful (models prior to v4 chargers). They go for a minimalist package, which helps to give the user constant visibility around the dispenser. However, some middle-ground approach should be used since the Tesla design leaves much to be desired by technicians who have to maintain the unit. Small

packages mean tight cavities that prolong maintenance activities like routing wires across the dispenser. Furthermore, the exact implementation would prevent features like having screens for instructions with alternate payment methods. It would be preferable if the screen were located at a reasonable height relative to the typical user's eye level, but it should not significantly impair their special awareness of what is behind the charger. I would propose either making the screen very thin and on the side of the charger, such that you do not have to shift your view around the device to see a person's silhouette, or the screen be placed at an angle at a height just below the average person's eye level. The latter option means you can peer over the screen to see beyond the dispenser but still have an experience where you do not have to position yourself in an awkward manner to use the screen. The angle screen option also would increase the internal volume of the enclosure and improve maintenance features. Adding a separate shading device, a system independent of the manufacturing of the dispenser, would reduce potential glare even with the angled screen idea. A cost-effective measure that dually addresses ambient lighting concerns is to use lamp posts with a suspended fabric shade between lamps. This shading would mitigate wear on the components of the dispenser by reducing operating temperatures and reducing exposure to water.

Automated security features could be added without much investment cost, utilizing a couple of sensors to identify tampering of cables, credit card readers, or even the power cabinet doors. Even though this strategy does not prevent tampering, it does speed up the time that the CPO can become aware of and address the incident. If the reliability of the sensor technology is sufficient, automated alerts to law enforcement might be viable and thus discourage further incidents. If the cost of this implementation is too much for all chargers to have, it can likely be a targeted effort to sites with historically higher rates of cable theft. Enclosing the charging cable

in a casing might also delay attempts to steal the cable. Upon payment for a charging session, a lock could disengage allowing the cable to be pulled out of the enclosure. This mechanism might also alleviate some of the effective weight the user would have to carry, as the cable is supported by the retracting system (like the retracting cables used with gasoline pumps).

Additionally, this means for the size of dispenser, a longer cable could be supported, increasing the support for vehicles with further charging port locations.

I would recommend standardizing chargers on CCS over NACS and CHAdeMO. CHAdeMO lags far behind the alternatives in terms of supported charging speeds, so it is not much of an option. Its isolation of DC charging is admirable, but I think it is impractical since it excludes AC home charging as an option. Even if a second port could be added to handle the AC charging option, it would complicate the user experience, requiring the user to understand the difference between AC and DC charging. NACS would be the better choice for the best user experience, but safety concerns with relying on AC/DC isolation protection warrants avoiding NACS and choosing CCS instead.

These changes are my recommendation for how the industry should move forward toward a more standardized EVSE package that attempts to prioritize the consumer while still maintaining value for other parties.

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