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Abstract

More than 110,000 PEVs are on the road in the United States, and the number of PEVs worldwide is rapidly growing. In parallel the U.S. is reaching the end of a large-scale PEV infrastructure investment. As this round of federal funding ends and these vehicles continue to sell, planning on the national scale will begin. It is important for key stakeholders to understand the number and relative location of PEV infrastructure. The results described here provide an estimate of the number of charging locations needed to support a national network or regional infrastructure, and can be used as a metric for approximate locations. For national planning this focuses on building a charging network based on two main analyses: the first concentrates on roadways and traffic and the second focuses on cities and towns. The results of this analysis do not assume exact number or perfect location of an electric vehicle supply equipment (EVSE), but instead give an approximation based on size and scale.

Keywords: charger, United States of America

1 Introduction

Plug-in Electric Vehicle (PEV) infrastructure is unlikely to be used frequently by battery electric vehicles (BEVs) because most charging will likely happen at home, overnight. However, these vehicles have the unique property of requiring some charging infrastructure in order to complete some (though unlikely most) daily driving. It is probable that drivers will self-select the car and electric range that best meets their needs, but providing a safe and reliable charging network is important for the acceptance and effective rollout of these vehicles. PHEVs, however, may benefit and wish to use some charging infrastructure. However, for long distance trips, depending on driving patterns, it may not be practical or cost effective to utilize the charging infrastructure. As described in the Electric Power Research Institute (EPRI) report *Guidelines for Infrastructure Planning* (1024102) [1], the PEV infrastructure has four main objectives:

- **Add miles to PHEVs (Level 1 or 2 AC):** Having charging available at work or in public locations may allow for PHEVs to add more electric miles to their trips, and therefore less gasoline miles.
- **Add comfort to BEVs (Level 2 AC or DC):** Unlike PHEVs, BEVs have only one fuel source, and require charging infrastructure. While most charging will occur at home and BEVs will generally have sufficient range for most driving days, having charging infrastructure should help subside range anxiety and hopefully encourage adoption and awareness.

- **Multi-unit dwelling (MUD) support (DC quick charging):** This paper does not explicitly address this. However, this is a very important aspect of secondary charging infrastructure, and one that may provide support to those without residential charging. This is particularly true in areas with high adoption rates and heavily concentrated, such as San Francisco or San Diego.
- **Enable longer trips for BEVs (DC quick charging):** The second objective to DC fast charging (and Level 1 or 2 AC, to some extent) is to enable longer trips for BEVs. While there is limited wide scale and rural charging infrastructure at this point in time, having even a small amount of secondary infrastructure can help enable longer trips in BEVs that would otherwise be inaccessible.

Secondary infrastructure is considered to be charging infrastructure that is not placed at home. It can be workplace or public, Level 1 or 2 AC or DC. Therefore, secondary charging infrastructure is not meant to be the primary fuelling source for PEVs. In fact, it is likely that secondary infrastructure will be utilized more by PHEVs than BEVs, especially in the early stages of infrastructure deployment. This is becoming increasingly true as markets develop and charging for charging begins to occur. This analysis does not analyze the benefit, actual number of stations, or relative need of charging. It focuses on placement and planning in geographic regions.

Dissimilar to previous EPRI analysis, this method focuses primarily on coverage and not necessarily the total number of EVSEs or the potential utilization of locations. This is for both a public safety network and regional planning. One method of PEV infrastructure planning is to use geographic information systems (GIS). GIS tools can offer insights into local, high-traffic corridors, population areas, and potential charging locations along roadways. By using existing roadways and towns, a coverage network can be created.

1.1 Key Results

The results of this analysis focus primarily minimizing the total number of locations of charging stations while still maximizing coverage. They can be summarized as follows:

- **If the purpose of a national PEV charging network is safety and coverage, it can be completed with 6, 265 locations for the lower 48 states.** Through examination of towns and major roadways, a national public safety network could be completed with this approximate number of locations – not necessarily chargers.
- **Examination of current EVSE locations in the U.S. is an important metric for determining what future metropolitan areas may decide to do.** Examination of current infrastructure installations shows the effect of both the impact public funding can have on infrastructure deployment and second, that metropolitan areas are better suited to install and site their own local infrastructure.
- **Connecting major metropolitan areas along heavily trafficked corridors has not been a focus yet in the U.S. and should be.** At the national and macro scale, some guidance may be useful to connect and build out this network. An example of this is the state of California. The state has invested and received significant investment for building out charging infrastructure. However, the major corridors connecting major cities are still lacking. It is a public service to connect these corridors.
- **This methodology can be applied to any country or region, with some adjustment.** The methodology explained in this paper simply provides guidelines for producing a national and regional networked solution. These results are easily repeatable on a country-by-country basis.

1.1.1 Application of Results

This paper describes one method for estimating locations of chargers and placement. As the number of PEVs on the roads increases, the number of charging stations will also need to increase, the results and numbers seen here will change.

2 National GIS Applications

When planning large (and likely expensive) infrastructure investments, it is important to create a network that has an expansive enough coverage that it provides a safety network for BEVs. This allows these vehicles to take trips that they would not otherwise be able to complete. The safety network focuses on connecting major roadways and corridors. A coverage network however focuses on placing EVSEs within a certain distance of certain towns and roadways.

EPRI has chosen to select all towns across the U.S. that have more than 2,000 people (based on 2000 U.S. Census Data), but not within metro areas of greater than 100,000 people. The two bounds were selected based on the idea that larger towns will build out their own charging infrastructure and the lower bound was chosen to show a reasonably low population while still not including every town. The results of this analysis are shown in Figure 1.

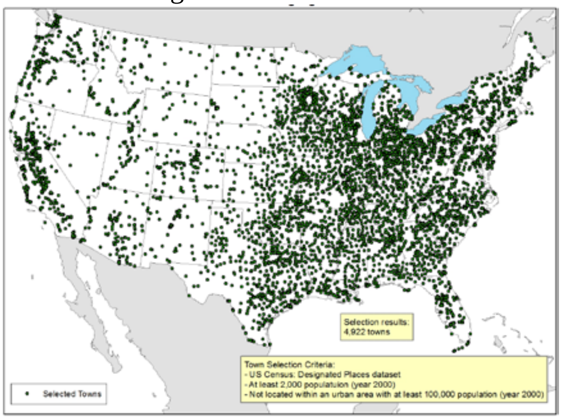

Figure1: National PEV charging network: town based

The results of the town based network show the stark population distribution between the western and eastern parts of the country. While not many people live in the central parts of the country, providing a networked solution may still be important. This results in 4,922 EVSEs.

In order to expand the national map so that coverage can extend past the town based network, we next move to a safety based network and examine major roadways. The roadway database we used here is the National Highway Planning Network and consists of the major roadways in the U.S., not just interstates. Figure 2 shows these roadways with an EVSE spaced every 20 miles, excluding the town areas that were included in the town-based network.

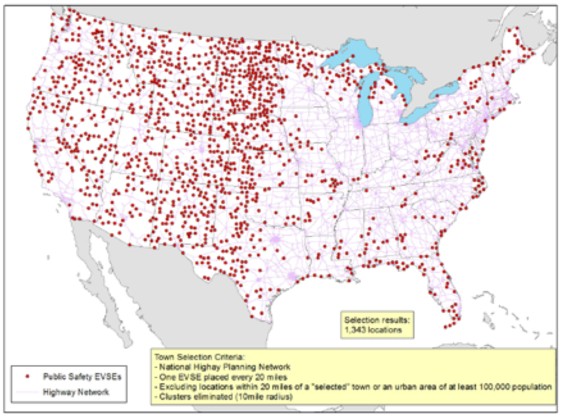

Figure 2: National PEV charging network: safety based

The results of the roadway network now begin to cover the previously spare west. This results in an additional 1,343 locations. This now begins to offer a safety network across the rest of the country.

The more interesting result, however occurs when we overlay the two maps, thus combining both the town based network and a safety network based on roadway travel. This is shown in Figure 3.

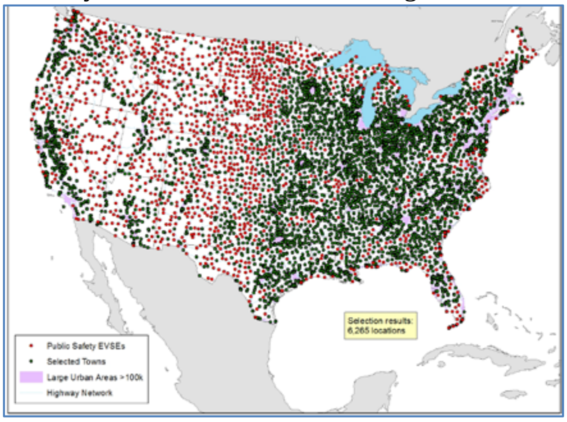

Figure 3: National PEV charging network: town and safety based

The coverage now for the road and town based network shows the relatively dense coverage across the eastern half of the U.S. We take this analysis one last step further and examine what this coverage will look like with a ten mile radius surrounding each charging location. This is shown below in Figure 4.

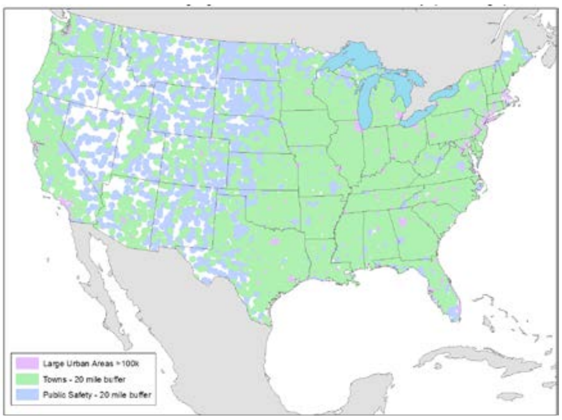

Figure 4: National PEV charging network: town and safety based with 20 mile buffer

Figure 4 shows the coverage map from the town and safety network. The results show that the majority of the country, or that which is traversed by vehicle and has a town in it, is safely covered for BEVs to travel. This results in a total of 6,265 EVSE locations.

Installing a charging network is extremely important. This encourages adoption, improves the mentality towards PEVs, and is likely to increase the distance to which individuals will drive their BEVs. There are non-trivial costs associated with this, but the potential societal benefit from PEV adoption may far outweigh the upfront costs.

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References

[1] *Guidelines for Infrastructure Planning.* EPRI, Palo Alto, CA: 2012. 1024102

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