NATIONAL RENEWABLE ENERGY LABORATORY

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Implementation Scenarios for Electric Vehicle Roadway Wireless Power Transfer

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Approach

Analysis was performed within seven Census Statistical Area (CSA) regions using corresponding second-by-second global positioning system (GPS) driving profiles from the Transportation Secure Data Center (TSDC).

- Three of the CSAs investigated, Kansas City, Chicago and Atlanta, were paired with TSDC data originally collected by metropolitan planning organizations from those regions.
- A separate California survey provided similar data on a statewide level which represents four CSAs within California: Los Angeles, San Francisco, Sacramento, and Fresno.
- Altogether, the data within these seven CSAs included 5,342 vehicle driving profiles totaling nearly one million miles of on-road data.

Infrastructure Placement

The Future Automotive Systems Technology Simulator (FASTSim) was used to simulate the fuel consumption that would be expected from five different Hybrid Electric Vehicle (HEV) models operated over the million miles of GPS driving profiles.

Relative to the total simulated fuel consumption over the full extent of the GPS driving profiles, roughly 70% of the fuel consumption took place within the designated CSA analysis boundaries, and roughly 30% occurred on functional class (FC)1 and FC2 road segments within the CSAs. The fuel consumption analysis in each region, with FC1 and FC2 road segments are ordered by the amount of fuel consumption occurring on them as shown in figure 1.

The charts on the right side of figure 1 suggest the leveraging opportunity from a small percentage of infrastructure may be even greater when considering fuel consumption than when considering overlap of vehicle miles traveled (VMT). Comparing fuel consumption across all regions, electrification of the top 1% of road infrastructure shows the potential to displace close to 25% of HEV fuel consumption within the CSA.

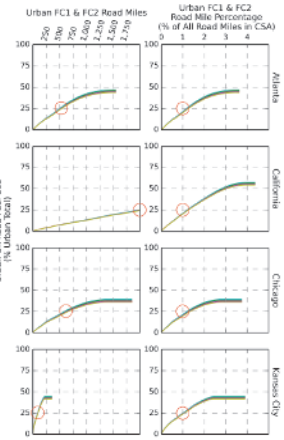

Figure 1. Fuel consumption reductions by WPT scenario for five HEV models

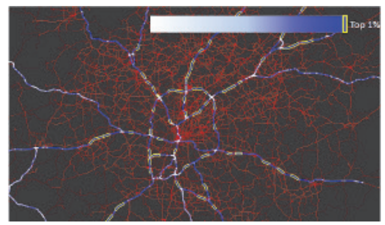

Figure 2. Infrastructure selection results for Atlanta

Grid Power for Roadway WPT

The infrastructure selection results for the top 1% of road miles in Atlanta and California are used to provide power demand for roadway WPT scenarios. The hourly power is calculated from the travel data in each region by determining the portion of fleet travel on the selected roads throughout the week. The total number of miles displaced is scaled for a fleet of 10,000 vehicles using the median weekly road miles travelled in each region.

This roadway power has been estimated for a fleet with an efficiency of 322.5 Wh/mile and a WPT efficiency of 80%. The power shown in figure 3 is only what is needed to drive the distances in the defined sections. A system that 'charges' the vehicles for operation in other road sections would be expected to provide more power in these electrified segments.

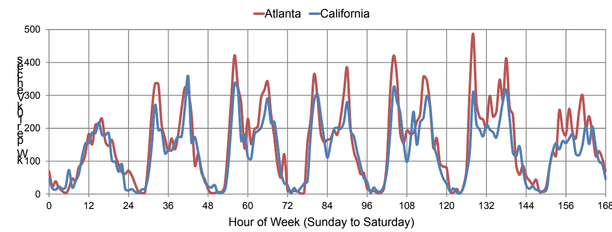

Figure 3. Grid power and roadway WPT system utilization

Grid Integrated WPT Infrastructure

Integration of energy storage and photovoltaics would allow for the WPT roadway to achieve an improved utilization of the grid-tied inverter throughout the day. These inverters offer a new opportunity for low-cost interconnection of renewables and distributed energy resources to the grid. The example system in figure 4 allows for the integrated resources to either directly power the inductive transfer system or provide grid resources through the grid-tied inverter.

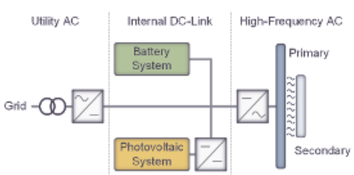

Figure 4. Integrated WPT system with renewable and energy storage resources

The capability of these resources to reduce the impact of the electrified roadway on the grid will depend on the temporal availability of each resource. Solar production data from the NREL Campus photovoltaic array has been averaged for the 2013 calendar year to provide a reference for a 60 kW solar resource. The coincident reduction of grid power for the Atlanta and California scenarios are include in figure 5. Note that the peak solar production occurs primarily during the midday lull of vehicle traffic on weekdays.

Integration of a 250 kWh energy storage system with a control algorithm designed to curtail the grid load at 300kW for Atlanta and 225 kW for California is shown in figure 5. These example systems demonstrate how peak demand power of the electrified roadway system can be reduced to minimize utility demand charges.

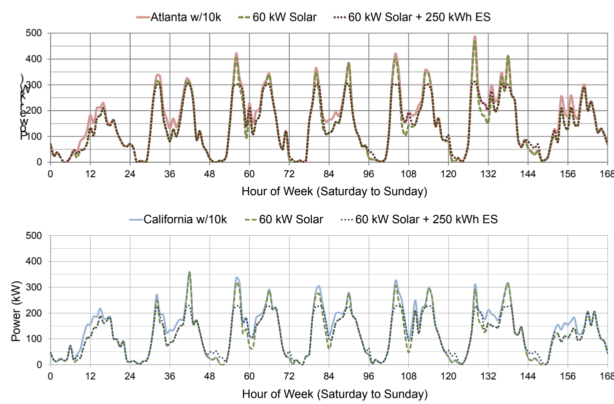

Figure 7. Atlanta and California Scenarios with Solar and Energy Storage

The systems were capable of reducing peak demand by over 125 kW in these hourly averaged scenarios. Interestingly with the 60kW solar system the afternoon peak energy used by the roadway is provided in the middle of each day. The energy storage recharged for the morning peak in late evening, however, the system still has very low utilization in the late evening hours. Therefore it is possible that acting as a distributed energy resource the integrated infrastructure could perform grid services such as frequency regulation during the evening hours.

Future Work

This analysis has given a preliminary assessment of roadway WPT rollout in CSAs along with the associated grid-level impacts. Future work to build on this assessment should:

- Develop a refined assessment of the intra-hour grid power dynamics.
- Explore cost benefits of grid integrated WPT grid infrastructure.
- Understand the tradeoff of intra– and inter-CSA WPT infrastructure.

Image by Josh Bauer, NREL

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