# NCHRP 08-36, Task 108
# Improving Travel Behavior Data for Alternative Fuel Vehicles: A Scoping Study

Requested by:

American Association of State Highway and Transportation Officials (AASHTO)
Standing Committee on Planning

Prepared by:

Texas A&M Transportation Institute
3135 TAMU
College Station, Texas 77843-3135
Principal Investigator: Stacey Bricka, Ph.D.

Cambridge Systematics
100 Cambridge Park Drive, Suite 400
Cambridge, MA 02140
(Prime Contractor)

Travel Behavior Associates

November 2012

The information contained in this report was prepared as part of NCHRP Project 08-36, Task 108, National Cooperative Highway Research Program (NCHRP).
**Special Note:** This report **IS NOT** an official publication of NCHRP, the Transportation Research Board, or the National Academies.

AASHTO
THE VOICE OF TRANSPORTATION

Acknowledgments

This study was conducted for the AASHTO Standing Committee on Planning, with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 08-36, Research for the AASHTO Standing Committee on Planning. NCHRP is supported by annual voluntary contributions from state Departments of Transportation. Project 08-36 is intended to fund quick-response studies on behalf of the Standing Committee on Planning. The report was prepared by Principal Investigator Stacey Bricka of the Texas A&M Transportation Institute. The project team included Anurag Komanduri and Sashank Musti from Cambridge Systematics (prime contractor), Nancy McGuckin from Travel Behavior Associates, and Chris Simek and Nick Wood from the Texas A&M Transportation Institute. The work was guided by a technical working group that included:

Tonia Buell, Washington State Department of Transportation
Rick Durst, Portland General Electric
Nathan Erlbaum, New York State Department of Transportation
Jeffrey Gonder, National Renewal Energy Laboratory
Catherine T. Lawson, State University of New York–Albany
Vladimir Livshits, Maricopa Association of Governments
Derek Miura, PTV America, Inc.
Elaine Murakami, Federal Highway Administration
Ed Tate, Exa Corporation

The project was managed by Lori L. Sundstrom, NCHRP Senior Program Officer.

***Disclaimer***

## TABLE OF CONTENTS


1.0 INTRODUCTION ..... 1
2.0 STAKEHOLDER PERSPECTIVES ..... 3
2.1 Automotive ..... 3
2.2 Utility ..... 4
2.3 Travel Behavior ..... 5
3.0 CURRENT DATA COLLECTION ACTIVITIES ..... 9
3.1 State of the Practice in Existing Data Collection Efforts ..... 9
3.2 Possible Data Gaps ..... 10
3.3 Data Collection Partnerships ..... 12
4.0 DATA COMMONALITIES MATRIX ..... 13
5.0 STAKEHOLDER MEETING OVERVIEW ..... 17
6.0 STAKEHOLDER MEETING SUMMARY AND KEY FINDINGS ..... 19
6.1 Introductions and Meeting Overview ..... 19
6.2 Project Scope and Preliminary Findings ..... 19
6.3 Data Commonalities ..... 20
6.4 Collaboration Levels ..... 21
6.5 Identification of Priorities ..... 21
6.6 Final Comments ..... 22
7.0 CONCLUSIONS ..... 23
8.0 SUPPORTING MATERIAL ..... 25
8.1 Literature ..... 25
8.1.1 Project Bibliography ..... 25
8.1.2 Automotive Literature ..... 28
8.1.3 Utility Industry Studies ..... 35
8.1.4 Travel Behavior Studies ..... 43
8.2 Interview Guide ..... 49
8.2.1 Automotive Stakeholder Questions ..... 51
8.2.2 Utility Stakeholder Questions ..... 52
8.2.3 Closing, asked of all stakeholders ..... 53

8.3 Interview Notes ..... 53
8.3.1 Task 108 Interview Summary #1 ..... 53
8.3.2 Task 108 Interview Summary #2 ..... 56
8.3.3 Task 108 Interview Summary #3 ..... 59
8.3.4 Task 108 Interview Summary #4 ..... 63
8.4 Stakeholder Workshop Discussion Guide ..... 66
8.4.1 Introductions and Meeting Overview ..... 67
8.4.2 Project Scope and Preliminary Findings ..... 68
8.4.3 Data Commonalities ..... 70
8.4.4 Collaboration Levels ..... 71
8.4.5 Identification of Priorities ..... 72
8.4.6 Final Comments ..... 72
8.5 Stakeholder Workshop Minutes ..... 73
8.5.1 Workshop #1 (Thursday) Minutes ..... 73
8.5.2 Workshop #2 (Friday) Minutes ..... 77
9.0 REFERENCES ..... 82

## LIST OF FIGURES

Figure 1: 2009 U.S. Electricity Generation by Source ..... 6

## LIST OF TABLES

Table 1: Data Matrix Depicting Key Variables in Evaluation of EV Market ..... 14

## 1.0 INTRODUCTION

In the past few years, increasing emphasis has been placed on understanding the market potential for electric vehicles (EV). Much of this research has been driven by concerns about preserving energy resources, combined with the current federal administration's stated goal of having one million EVs on the road by 2015. Studies on the topic span the spectrum, from driving profiles that inform vehicle design, in-vehicle diagnostics, and mobile computing components, to early adopter usage patterns that help site public recharge stations and determine the impact of vehicle charging on the electric grid. Although consumer demand has been lower than anticipated, findings indicate that auto manufacturers are aggressively marketing their products to specific market segments and EVs are being adopted by users across the country. As such, there is an urgent research need to assess the potential impact of wide-scale penetration of EVs and related driving behavioral changes on transportation resources and the electric grid.

In recognition of the potential value of travel behavior data in informing EV research, the AASHTO committee on research funded an exploratory research effort to better understand the connectivity between travel behavior data and EV research under the NCHRP Quick Response program. The resulting NCHRP 08-36C Task 108 project evaluated the extent to which travel behavior data would be useful in supporting this type of research and identified the possibilities for and barriers to collaboration. The research found that collaboration across different stakeholder groups could result in an efficient use of research funding through sharing data, combining and prioritizing research efforts, and disseminating results. The findings also suggest that stakeholders could benefit from such collaborations that reduce the net spending of each group on data collection. In turn, the fine-grain details collected as part of these efforts could support the development of advanced analytical approaches for all stakeholders.

The purpose of this report is to summarize the research conducted as part of the NCHRP 08-36C Task 108 project, and related findings. This includes the literature review, data collection, and stakeholder interviews that were used to build the theoretical foundation, which in turn guided the development of the agenda for the stakeholder meetings. The stakeholder meetings confirmed the findings of previous efforts and helped prioritize how to best continue this collaborative effort.

Throughout the research, the EV research community/stakeholder group was broadly divided into three groups:

- *Automotive:* Automotive stakeholders are those who manufacture or work in partnership with manufacturers to identify strategies to enhance the operations of these vehicles.

- *Utility:* Utility stakeholders are those associated with the infrastructure necessary to support the EV market. This includes the utility companies and those companies associated with installing and maintaining the recharge stations.

- *Travel behavior:* Travel behavior stakeholders are those who study travel behavior and evaluate and implement policy changes to improve the overall performance of transportation networks.

Although the research was centered on those three groups, many stakeholders were interested in multiple aspects of the EV research and did not belong exclusively to any one category. Examples of these cross-group stakeholders include the Idaho National Laboratory and the National Renewable Energy Laboratories.

Also, the title of the project refers to "alternative fuel vehicles," which could include a broad spectrum, from EVs to those fueled by natural gas and other sources. Early in the project, the project panel agreed to focus specifically on EVs only. This provides for the broadest mix of stakeholder perspectives because it includes utility companies and their research in the discussion.

The research effort was organized around three tasks:

1. *Reconnaissance:* This includes identifying existing issues and data needs among stakeholders and supplementing the literature review results with one-on-one interviews.

2. *Stakeholder meetings:* The results from the first activity were used to develop interagency stakeholder meetings, which served to confirm the findings to date and to prioritize research issues that would support stronger collaborative efforts and a better understanding of shared data needs.

3. *Document:* The intent of Task 108 was to develop a research problem statement for the fiscal year 2013 funding cycle. However, after conducting the research, the oversight panel concluded that ***at this time*** there is no compelling research question appropriate for NCHRP. Instead, the research team prepared this final report to set the stage for future collaboration and research.

The results from the project are presented in this report, which is organized as follows: Following this introduction, the stakeholder perspectives are summarized, based on the literature review and interviews conducted. This is followed by a brief outline of the relevant data elements for each stakeholder group in Section 3 and a summary of the data needs for each stakeholder group in Section 4. Section 5 provides an overview of the stakeholder meetings, with the key findings from those interviews noted in Section 6. Section 7 presents the team's recommendations regarding activities that could serve to keep the collaborative momentum moving. All the supporting materials referenced in this document are included in Section 8.

## 2.0 STAKEHOLDER PERSPECTIVES

As part of this effort, an extensive literature review was conducted to identify the state of the practice with regards to data needs to support EV research, as well as evidence of collaborative efforts and/or related barriers. The results of that research are presented here, generally divided into the automotive, utility, and travel behavior stakeholder groups.

### 2.1 Automotive

Volatile fuel prices and concerns about global warming and greenhouse gas (GHG) emissions are all contributing to a greater scrutiny by households as they make long-term automobile investments. In an era of increasing technological advances, consumers are looking to the automotive industry to design alternative technologies that can help solve or at least alleviate these issues. The automotive industry has responded, in part, by investing in plug-in electric vehicle technology that uses energy sources other than petroleum to fuel vehicles. This new fleet of vehicles promises a viable solution to our existing transportation energy problems. There are two broad categories of EVs:

- *Battery electric vehicles* (BEVs) are vehicles that run solely on electrical energy and obtain this energy through an onboard battery, which is charged by a cord that can be plugged into the grid (MIT, 2010). An example of a BEV is the Nissan Leaf.

- *Plug-in hybrid electric vehicles* (PHEVs) have an on-board fuel converter in addition to batteries that charge from an off-board electricity source (Vyas et al., 2009). A Toyota Prius plug-in hybrid is an example of a PHEV.

Some key factors, identified through both the interviews and literature review, likely to impact consumer perception and influence adoption of this new fleet of vehicles include the following. Each of these topics is being studied extensively and requires detailed information from either a survey panel or from controlled experiments.

- *Higher purchase cost:* EVs tend to be more expensive than their conventional gasoline counterparts, estimated to cost $8,000 more than a conventional vehicle (Simpson, 2006), making value differentiation an important component of vehicle design. Higher purchase costs reflect both the high manufacturing costs of batteries and the nascent stage of battery technology (Calcars, 2003; Simpson, 2006). Higher purchase costs tend to be a major deterrent for consumers who intend to adopt these vehicles (Morrow et al., 2008; EPRI, 2010; Simpson, 2006; Musti and Kockelman, 2011). High adoption rates can be attained by mass production and lower manufacturing costs.

- *Battery technology:* Ownership costs are also dependent on the costs associated with charging the batteries, which in turn are impacted by factors such as battery size, battery type, and type of infrastructure available for charging (Smart et al., 2010). A study by Morrow et al. (2008) showed that level 2 chargers, which take around two hours to charge a 10 kWh battery, would cost $2,146 in residential garages, $1,520 in apartment complexes, and $1,852 in commercial facilities. Further, consumer perception, which plays an important role in adopting new technology, appears to be dependent on charging

time, which varies by battery size and type of charging available (EPRI, 2010; Vyas et al., 2009).

- *Travel range:* Consumers' anxiety about the electric range was noted as a key obstacle to adopting EVs (Tate et al., 2009). EVs with higher price tags are often accompanied by higher electric range, lower fuel consumption, lower carbon footprint, and, in most case, lower adoption rates. Identifying an optimal electric range will thus be beneficial both for auto manufacturers and consumers alike. To better understand this relationship, Vyas et al. (2009) analyzed the 2001 National Household Travel Survey (NHTS) data and concluded that an EV range between 10 and 20 miles would help consumers reduce their fuel consumption and suit their travel plans more efficiently than other ranges. Zhou et al. (2012) analyzed the 2009 NHTS data and concluded that pickups are not used that often and that vehicles such as cars, SUVs, and vans would be ideal EVs.

Both Gonder et al. (2007) and Markel et al. (2009) analyzed 24-hour, second-by-second driving profiles of 227 global positioning system (GPS)-instrumented vehicles from St. Louis. Their research focused on fuel savings and opportunity charging. They concluded that a PHEV20 reduced fuel consumption by 20 percent, and a PHEV40 reduced fuel consumption by 66 percent, but through opportunity charging a PHEV20 would reduce fuel consumption by 71 percent. Khan and Kockelman (2012) studied the driving behavior of 264 households over a one-year period and concluded that net energy cost savings appear to be higher for PHEVs than BEVs. Also, multiple-vehicle and multi-day GPS data from households could be much more useful to further the understanding of vehicle use.

Tate and Savagian (2009) conducted a thorough analysis of the 2001 NHTS data that focused on fuel use, carbon dioxide displacement, and grid impacts of various vehicle technologies. In addition, several studies point to the effect of driving conditions, topography, weather conditions, ambient environmental conditions, and cruise control systems on the performance of plug-in electric vehicles (Loiselle et al., 2010; Carlson et al., 2010; Moran et al., 2010).

## 2.2 Utility

Public utilities attempt to optimize their energy systems to meet the demands of their customers as efficiently as possible by generating and transmitting a finite amount of electricity during a set period of time. Given the anticipated proliferation of EVs, utilities are planning for them as an additional customer market drawing power from the grid and, longer-term, potential energy storage units as well.

Consequently, utilities face a new challenge of "*how to meet the increased demand from EVs while maximizing efficiency.*" To effectively plan for this scenario, utilities desire to model consumer electric demand. To do so, utilities require data such as:

- Market penetration forecasts for EVs that allow an understanding of the number of EVs drawing power from the grid;

- Understanding of trip factors such as average trip length and frequency of trips that influence EV charging; and

- Consumer charging behavior such as the location, frequency, time of day, and duration of EV charging events.

These data will allow public utilities to play a vital role in ensuring that the grid is sufficient to meet the needs of all their customers, while providing good customer service. Several strategies are being considered:

- *Smart charging:* One proposed strategy is to offer "time of use charging" or "managed charging" where electricity is sold for EV charging at reduced prices during off-peak hours such as late night and early morning hours. The use of smart meters may be used to help facilitate smart charging. They can also simultaneously act as a mechanism to provide data back to the utility, which can use the data to better understand the charging behaviors of EV-owning utility customers.

- *Vehicle-to-grid communication:* Another strategy that may help utilities optimize their systems is implementing vehicle-to-grid technology—EVs become mobile electric storage devices.

Utilities are looking to private business as potential partners in helping manage how and where EV owners charge. This may be accomplished by private businesses offering employees the use of EV charging stations. In turn, these charging stations will funnel information back to the utility on EV owner charging behavior. The installation of these non-residential charging stations will also help manage the issue of "range anxiety," which, in turn, may help increase EV market penetration.

### 2.3 Travel Behavior

Electric vehicles are attractive to policy makers and consumers interested in reducing GHG emissions from mobile sources. Manufacturers are interested in how consumers weigh the advantages and disadvantages of different types of EVs. Utilities are concerned about charging behavior but see a potential for storing renewable energy in the batteries of a fleet of EVs. Overall, EVs are seen as one of the most promising options for adding diversity in fuel type to the current fleet.

Manufacturers are interested in how attractive EVs will be to the U.S. consumer and are interested in understanding the question, "*Will people trade the disadvantage of range limits and recharging time for a vehicle that is seen as green and clean?*" Although currently EVs are considered green, the extent to which they reduce GHG emissions depends on the energy mix used to recharge the battery and the driver behavior. Theoretically, in a perfectly transparent and free-market energy world, the driver can choose whether to run the EV off conventional electrical energy sources or strictly from renewable electrical energy sources. But in the current market, many EV owners in the United States will be recharging at home or at work from electricity primarily generated from coal, natural gas, and nuclear (see Figure 1).

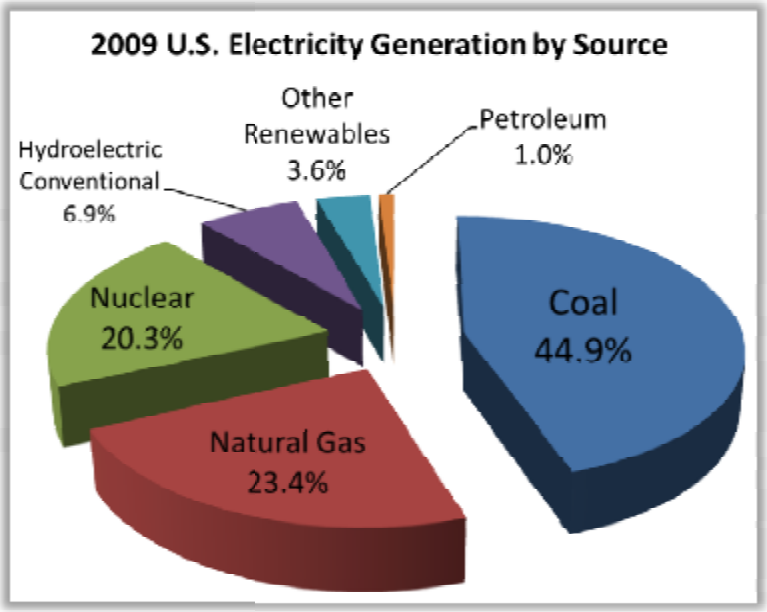


**Figure 1: 2009 U.S. Electricity Generation by Source**

*Source: [http://mapawatt.com/2010/11/29/where-does-u-s-electricity-come-from/](http://mapawatt.com/2010/11/29/where-does-u-s-electricity-come-from/)*

In addition to considering the trade-off between limited range and "clean and green" driving, other EV-related questions include:

- Will customers pay a premium for a vehicle that removes the need to go to a gas station? For example, do customers exist who are willing to accept a limited range between charges in exchange for eliminating the need to stop at gas stations? Would the availability of a hands-free charging system change the acceptance of this trade-off? How does the number of hours/year at the gas station correspond with daily range requirements?

- Does the availability of an onboard vs. off-board range extender change the perception of "green and clean"?

- Are customers interested in adding an EV to their household fleet as a hedge against gas prices? How much premium are they willing to pay for this kind of hedge? How does the relationship between household fuel expenses correspond with daily driving requirements?

- Would the ability to use an EV/PHEV as a household backup power supply/generator change customers' perception of the usefulness of an EV? How does backup generator ownership correspond with household fleet composition and driving needs?

The attractiveness of EVs for electricity providers depends on charging behavior and the practical storage capacity. Utilities are interested in how owners of EVs will recharge the

vehicle. Will they come home from work, plug in the car, flip on the air conditioner and the big-screen TV, and overload the grid?

If that is the expected behavior, then steps should be taken to regulate charging, either through user education or hardware such as delayed charging units. Interestingly, through sites such as http://voltstats.net/, EV owners are willingly sharing vehicle usage data. In exchange, they use the real-time feedback from their vehicles to improve driving patterns, and social reporting sites like http://voltstats.net/ to "compete" with other EV owners in their community or region in terms of improving driving stats. This gaming approach to EV ownership has been noted in the Southern California EV market and is expected to grow with increasing market penetration.

Over time, EVs have the potential to contribute to the integration of renewable energy sources into the electricity grid because the battery technology offers a way to store renewable energy. Therefore, utilities have a natural interest in EVs since they are a potential link between the energy supply on one hand and use of batteries as storage of the excess supply of sustainable energy production on the other.

## 3.0 CURRENT DATA COLLECTION ACTIVITIES

The main interest in collaboration across these stakeholder groups centers on the sharing of data, be it data that have already been collected or in collaborating in survey design and funding. As part of this effort, the research team documented the data used in EV research efforts to identify synergies with the data obtained through household travel surveys, particularly those with GPS subsamples. This section summarizes the findings with regards to possible data synergies among the stakeholder groups.

### 3.1 State of the Practice in Existing Data Collection Efforts

From an *automotive* perspective, and to the same extent from partner industries like *mobile computing* and *national laboratories*, access to longitudinal large-scale random sample studies such as regional or statewide travel surveys would be ideal. Current data collection efforts are based on convenience samples, which tend to be smaller but cover a longer duration. For example, a Microsoft study obtained data from a choice sample including three components: an in-vehicle GPS sample of 317 vehicles over a time period of two weeks to a year, a 54-person wearable GPS sample, and a commercial vehicle sample of 350 vehicles.

In the absence of such data, researchers rely on the NHTS. The 2001 NHTS was used to estimate travel ranges, while the 2009 NHTS helped to inform household fleet composition and household vehicle ownership profiles where an electric vehicle might become a second or third household vehicle. Additionally, GPS data streams from regional travel survey data sets have been used to establish driving profiles.

In the *utility* industry, to date, there have been a variety of EV-related data collection efforts. For instance, the Electric Power Research Institute (EPRI) conducted survey research projects across the United States in an attempt to understand the issues of EVs and EV owner behavior. A sample of the topics covered included consumer purchasing behavior, charging access, choice preference, and willingness to pay. Some key findings of the research state the following:

- Consumers do not understand the terminology used by the EV industry.
- Regional and cultural influences have a huge impact on EV consumer behavior.
- Consumers prefer quicker charging options.

A few demonstration projects have been implemented to collect real-world EV and EV user data. For example, a study was recently conducted by General Motors, OnStar, and Raleigh NC Utility, in which OnStar-enabled Chevy Volt model vehicles were driven by employees of electric utilities. The OnStar system transmitted onboard data from the vehicle to the utility to help predict grid demand, establish charging rates, and locate charging facilities. OnStar was also used to transmit real-time updates on electric rates to gauge the consumer response to various charging plans.

Several trade organizations are promoting EVs, including the American National Standards Institute (ANSI), EPRI, SAE International (SAE), Electric Drive Transportation Association

(EDTA), Electric Vehicles North Texas (EVNT), Institute of Electrical and Electronics Engineers (IEEE), National Science Foundation Center Effort on PHEVs/BEVs, Idaho National Laboratory (INL), and Edison Electric Institute (EEI).

From a *travel behavior* point of view, almost all of the studies in the literature review use data from conventional surveys (e.g., metropolitan planning organization, state, and the NHTS) and extrapolate behavior of conventional car owners. Many of the studies looked at average vehicle miles traveled per day for the average driver and various demographic or geographic groups to assess possible market penetration of EVs with a limited range of operation without recharging (Elgowainy et al. 2012; Chlond and Kagerbauer 2012; Aultman-Hall et al. 2012)

### 3.2 Possible Data Gaps

In addition to considering available data, the research also considered data that was desired but for which a clear source does not currently exist. This section presents what appear to be unmet data needs.

- *Automotive:* The key data gap for the automotive industry appears to be the unavailability of long-term large-sample GPS data sets (in at least one case, "long term" was defined as about a year's worth of data). This data gap is also keenly felt in the mobile computing industry. These longer-term data provide insights into the consistency of driving patterns and places visited and help develop custom driving profiles. Other data gaps include the opinions, needs, and expectations of the consumers themselves, as well as their real-world fuel consumption and driving patterns (again a reference to the long-term data sets). For the mobile-computing industry, the data needs surround the objective of giving travelers real-time and relevant information about destination options. Again, longer-term travel patterns provided through GPS traces help to more accurately estimate habitual travel, which leads to more accurate predictions.

  In addition to data about driving patterns, other automotive data gaps may include the following:
  - *The linkage of vehicle usage patterns to the onboard diagnostic (OBD) data that captures data from the vehicle's controller area network (CAN):* This would provide data such as vehicle speed and odometer readings (to help validate/correct error from GPS readings), fuel use, ambient/cabin/engine temperature, and whether the headlights or windshield wipers are operating.
  - *Household fleet usage/utility:* Collecting data on a single vehicle is not sufficient. The use of other vehicles in the household should be considered. One of the interesting possibilities in North America is that EVs may make a good second or third vehicle. Knowledge of how a household fleet is used with unlimited-range and limited-range vehicles would be a valuable data point to identify potential market segments and vehicle characteristics.
  - *Vehicle passenger usage/utility*: Collecting data on the number of passengers in the vehicle would assist in understanding the need for one-, two-, four-, five-, or multi-passenger vehicles and how they are used. These data might be able to be collected using in-vehicle cameras or monitoring door openings and serial data messages for passenger presence detection.

- *Cargo utility:* Vehicles are used to transport passengers and cargo. An estimate of when and how much cargo is moved would be helpful when assessing the utility of alternative vehicles. Cargo usage could be estimated using journals, interviews, in-vehicle cameras, trunk light/opening detection (e.g., check when the trunk lid light comes on or rear hatch light comes on).
- *Towing utility*: Vehicles are occasionally used to tow items. This could be assessed using journals, interviews, or, in some vehicles, a sampling of the rearview camera.
- *Range reserve:* The behavior of drivers in maintaining a range reserve should be measured. The effect of charging availability away from home and the availability of good navigation information on charging stations, weather, etc. should be considered. Additionally, a survey should try to identify if EV drivers maintain a range reserve or if they ignore remaining range when using the vehicle. Another interesting question is if an EV driver reduces energy consumption (e.g., heating and air conditioning) and speed as the remaining range nears 0.

- *Utility:* The stakeholder interviews revealed two significant data issues. First, public utilities have a difficult time accurately estimating the number of EVs in their utility service area due to the scarcity of public data regarding this small market segment, as well as the reluctance of auto manufacturers to share vehicle sales data. Somewhat related to this is the general lack of knowledge public utilities have regarding regional household travel survey data collection. It may be possible that much of the data desired by public utilities is already being collected (particularly vehicle type, trip-related variables, and residence type). Other data elements that have been identified as potentially useful for the utility industry include longitudinal snapshots of travel behavior, geographic distribution of trip ends, trip lengths, time of day, number of electric miles, charging location, time of charging, parking location, and charging preferences.

- *Travel behavior:* Estimates of potential market shares for EVs have ranged from 3 percent to more than 75 percent (Chlond and Kagerbauer [2012], Aultman-Hall et al. [2012]). One conundrum is that many people who drive a few miles each day and therefore might not be constrained by the mileage limit of an EV belong to low-income categories and are unlikely to purchase a new EV. Basing the market penetration on current mileage alone appears to be flawed. Other studies look at second or third vehicles in the household as a potential for EV adoption.

  In addition to understanding how ownership of an EV might change travel behavior, there is also interest in how the EV data might help to inform the development of advanced travel demand models. The advanced models (particularly activity-based models like TRANSIMS) rely on actual sequential origin-destination patterns and require more detailed data than the traditional trip-based models. The GPS data captured by EVs could advance travel behavior modeling and help to provide detailed data necessary to address shortcomings in current model designs.

- *Charging behavior:* Charging behavior and associated constraints appear to be a data gap. One exception found was a demonstration project where 40 households were given an EV and the charging behavior was observed (Davies and Kurania, 2010). This study

assessed human behavioral patterns, such as whether EV owners would charge the vehicle at a friend's house while visiting. One interesting note on charging behavior (Christensen, 2010) is that in order for EV batteries to function as storage for renewable energy, such as wind, drivers will need to connect the vehicle to the grid even when they do not have to charge in the event that the stored energy is needed.

- *Natural driver behavior:* Some EVs offer real-time feedback to the driver on energy efficiency while the vehicle is in use. The interviews and literature suggest that EV owners are willing to share vehicle operating data, which can be useful in understanding how early adopters respond to real-time feedback and adjust their driving habits to be more eco-friendly. These driver-supplied data are used by the automotive and utility industries, while other studies have focused on GPS data sets for this analysis. For instance, one study used a GPS data set collected for a road pricing study as a source, while another simulated naturalistic driving behavior from the 2001 NHTS (Pellon et al., 2010).

- *Attitudinal data*: Interestingly, general attitudinal data were not considered as important as the travel pattern data. However, as the EV market grows, understanding range anxiety, charging patterns, and how the instant feedback from the vehicle technology affects driving patterns will all impact usage. In addition, attitudinal data will allow researchers to track changes in battery/range reserves based on whether the trips are taking place in areas with good public charging infrastructures versus those without, and with/without the availability of maps and navigation systems that show charging availability.

### 3.3 Data Collection Partnerships

In the automotive industry, the main players are the automotive manufacturers themselves alongside industry associations like SAE. Partner agencies include mobile computing developers like Google, Microsoft and Apple, and the National Laboratories. The secure data centers and availability of cooperative research agreements, in particular, have resulted in the National Laboratories having strong partnerships with automotive manufacturers.

While some public utilities have sponsored or participated in research efforts, the literature suggests that the majority of data collection efforts have been initiated by private companies (particularly auto manufacturers) or trade organizations (such as EPRI, SAE, EDTA, EEI, and Plug-In America). It should also be noted that Idaho National Laboratory has contributed a significant amount of research to the overall body of EV research, and grassroots sites promote public data sharing and competitions using driving statistics among EV owners.

In the travel behavior arena, a lot of research is being conducted by academics at the universities. Regional transportation agencies are involved on the planning side, through the development of location standards for electric vehicle charging stations and the designing of regional electric vehicle readiness plans.

## 4.0 DATA COMMONALITIES MATRIX

The following matrix (Table 1) presents a summary of data needs across the stakeholder groups. Variables are organized into categories. Then for each category, indicators regarding commonalities across stakeholder groups are presented.

**Table 1: Data Matrix Depicting Key Variables in Evaluation of EV Market**

¢ Significant Impact; ¤ Some Impact; £ Minimal Impact; ü Yes; û No; --- Not Applicable; * Already in Travel Surveys

| | Variable Name | Commonly Included in Travel Survey and Related Efforts? | Level of Detail | Most Common Use in Travel Behavior Analysis | Relevance to… | | | Obtained through…Surveys | | | Privacy Concerns | Easy to Incorporate in Travel Survey Efforts? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Automotive Industry | Utility Companies | Travel Behavior | National | Regional | Custom | | |
| Socio-demographics | Home type | ü | *Multi-family home Single-family home* | Land use modeling | ¢ | ¢ | ¤ | ü | ü | ü | û | * |
| | Household income | ü | *Annual household income categories* | Trip rates Mode choice | ¤ | £ | ¢ | ü | ü | --- | û | * |
| | Number of workers | ü | *Full-time worker Part-time worker Looking for job Not seeking employment Retired Homemaker* | Trip rates Joint travel analysis | £ | £ | ¢ | ü | ü | --- | û | * |
| | Household Lifecycle | ü | *Single Married with no kids Married with children Retired* | Longitudinal household travel analysis | ¤ | £ | ¢ | ü | ü | ü | û | * |
| | Residential location | ü | *Detailed Address City Zipcode* | Trip generation Long term residential choice | ¢ | ¢ | ¢ | ü | ü | ü | ü | * |
| | Workplace location | ü | *Detailed Address City Zipcode* | Trip generation Destination choice | ¢ | ¢ | ¢ | ü | ü | ü | ü | * |

| | Variable Name | Commonly Included in Travel Survey and Related Efforts? | Level of Detail | Most Common Use in Travel Behavior Analysis | Relevance to… | | | Obtained through…Surveys | | | Privacy Concerns | Easy to Incorporate in Travel Survey Efforts? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Automotive Industry | Utility Companies | Travel Behavior | National | Regional | Custom | | |
| Vehicle Ownership & Travel Behavior | Trip lengths | ü | *By Individual Time-of-Day Purpose Route* | Destination choice | ¢ | ¤ | ¢ | ü | ü | ü | û | * |
| | Driving behavior | ü | *Number of Stops Braking-Accelerating Refueling* | Safety modeling Stop generation in ABM | ¢ | ¤ | ¤ | û | û | ü | ü | * |
| | Vehicle fleet composition-character-istics | û | *Number of vehicle(s) Type of vehicle(s) Age of vehicle(s) Actual fuel efficiency* | Mode Choice Auto ownership models | ¢ | £ | ¤ | ü | ü | ü | û | ü |
| | Long-term vehicle purchasing behavior | û | *Evolution of fleet Average payback period* | Long term vehicle ownership choice | ¢ | £ | ¤ | û | û | ü | û | û |
| | PHEV/EV type | û | | --- | ¢ | ¢ | £ | û | û | ü | û | ü |
| | Vehicle use behavior | û | *Primary vehicle for short vs. long trips/ single vs. joint trips/ work vs. non-work* | Mode choice | ¢ | £ | ¢ | û | û | ü | û | û |
| Geographic (Secondary Sources) | Fuel costs/gas price | ü | *Collected from secondary sources* | Transit modeling Mode choice | ¢ | ¢ | ¢ | ü | ü | ü | û | * |
| | Topography | û | *Gradient Curvature Elevation Change* | Bike plans | ¢ | £ | £ | û | û | ü | û | û |
| | Roadway congestion & reliability | ü | *Collected from secondary sources* | Traffic assignment ToD Models | ¢ | ¤ | ¢ | û | ü | ü | û | * |
| | Weather | û | *Collected from secondary sources* | Safety modeling | ¢ | ¤ | £ | û | û | ü | û | ü |

| | Variable Name | Commonly Included in Travel Survey and Related Efforts? | Level of Detail | Most Common Use in Travel Behavior Analysis | Relevance to… | | | Obtained through…Surveys | | | Privacy Concerns | Easy to Incorporate in Travel Survey Efforts? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Automotive Industry | Utility Companies | Travel Behavior | National | Regional | Custom | | |
| Charging Behavior | Availability of carport at home | û | *Household-level charging infrastructure* | --- | ¢ | ¢ | £ | û | û | ü | û | ü |
| | Location of charging | û | *Res. vs. Work Grocery stores Private stations* | Regional PHEV/EV Planning Studies | ¢ | ¢ | £ | û | û | ü | ü | ü |
| | Frequency of charging | û | *How often? What type of charging station used? How long was the vehicle charged?* | --- | ¤ | ¢ | £ | û | û | ü | û | ü |
| | Duration of charging | û | | --- | ¢ | ¢ | £ | û | û | ü | û | ü |
| | Time of day of charging | û | *Overnight charging Topping off Workplace charging* | --- | £ | ¢ | £ | û | û | ü | û | ü |
| | Charging infrastructure | û | *Level I/II/III* | --- | ¢ | ¢ | £ | û | û | ü | ü | ü |
| | Battery technology | û | | --- | ¢ | ¤ | £ | û | û | ü | ü | û |
| Attitudinal | Charging preferences | û | *Behavioral questions that target acceptance of various infrastructural and technological advances. Support market assessments.* | --- | £ | ¢ | £ | û | û | ü | ü | û |
| | At home charging plan preferences | û | | --- | £ | ¢ | £ | û | û | ü | ü | û |
| | Willingness to pay for managed charging | û | | --- | £ | ¢ | £ | û | û | ü | ü | û |
| | Reliance on subsidies to purchase PHEV/EV | û | | --- | ¢ | ¤ | £ | û | û | ü | ü | û |
| | Green consumer | û | | --- | ¢ | ¢ | £ | û | û | ü | ü | û |

## 5.0 STAKEHOLDER MEETING OVERVIEW

The goals of the stakeholder meetings were to assemble a cross-industry panel of stakeholders and to obtain their reactions and input to the preliminary research findings. Since there were no suitable forums for in-person meetings during this time period, the team hosted two web-based workshops, on Thursday July 5, and Friday, July 6, 2012. These meetings followed the format outlined in **Section 8.0 Supporting Material, 8.4 Stakeholder Workshop Discussion Guide** in this report. The meeting dates and times were set based on the stated availability of interested stakeholders.

More than 50 stakeholders representing the automotive, utility, transportation, and related industries were invited to the workshops. This included panel members, those who participated in the interview process, those who declined the interview process, and those who had not responded to requests for any prior activities. To provide maximum opportunity for discussion, two workshops were scheduled. The following is a summary of who attended each meeting:

- Thursday, July 5, 2012:
  - *Panel members:* Jeff Gonder of the National Renewable Energy Laboratory (NREL), Vladimir Livshits of the Maricopa Association of Governments, and Elaine Murakami of the Federal Highway Administration (FHWA); and
  - Greg Giaimo of the Ohio Department of Transportation (modeler), Bernard Neenan of EPRI (utility industry), and John Smart of the Idaho National Laboratory.

- Friday, July 6, 2012:
  - *Panel member:* Tonia Buell of the Washington State Department of Transportation; and
  - Jeff Barghout of Advanced Energy (NC), Reza Farzeneh of TTI, Diego Klabjan of Northwestern University, John Krumm of Microsoft, Nukal Sathaye of Ecotality, Eric Wood of NREL, and Charles Zhu and Nick Nigro of the Center for Climate Energy Solutions.

Given the importance of these meetings, special care was taken to ensure that the meetings involving stakeholders with varied backgrounds went smoothly. An extensive review and testing of web-based meeting software packages was conducted, and a professionally trained moderator was included to facilitate the discussions. Further, a detailed discussion guide was developed to manage the meeting flow. In addition, the TTI team members attended a webinar on conducting effective web-based meetings prior to the sessions.

Ultimately, the meetings were held using Adobe Connect web meeting software. This was provided courtesy of panel member Elaine Murakami. Only one attendee had problems connecting, apparently due to a firewall issue. This was remedied by providing that person with the PowerPoint files so that he could follow along on his screen.

Each workshop lasted approximately two hours. Detailed notes of the discussions are provided in **Section 8.0 Supporting Material, 8.5.1 Workshop #1 (Thursday) Minutes,** and **8.5.2 Workshop #2 (Friday) Minutes**. The meeting outline was tailored to inform the project's research objectives. This included the discussion and identification of a framework for better

coordination of travel behavior data collection and accessibility across multiple stakeholder groups. The meeting details are presented in Section 6, along with key findings relevant to this effort.

# 6.0 STAKEHOLDER MEETING SUMMARY AND KEY FINDINGS

The meeting was subdivided into six sections to better manage the discussions. These include:

1. Introductions and Meeting Overview,
2. Project Scope and Preliminary Findings,
3. Data Commonalities,
4. Collaboration Levels,
5. Identification of Priorities, and
6. Final Comments.

Each of these items is summarized below, including input from the stakeholders and key findings where appropriate.

## 6.1 Introductions and Meeting Overview

The meeting opened with a general review of the software and presentation of the meeting objectives. These included:

- vetting preliminary research regarding the commonalities that exist between travel behavior and EV research;
- discussing whether some type of data-sharing partnership could work, possible barriers preventing such a partnership, and what was needed to support collaboration; and
- gathering input from the group on the priorities of the research needs identified.

Attendees were next asked to provide their name, affiliation, and key areas of research in this topic area. The first group was primarily transportation affiliated but did include representatives from EPRI and the Idaho National Laboratory. The second group primarily consisted of EV researchers.

## 6.2 Project Scope and Preliminary Findings

The next part of the meeting presented information about NCHRP, relevant transportation data, and preliminary findings.

In the first group, most attendees were familiar with NCHRP, but in the second group, not as many attendees were aware of the program. Non-transportation stakeholders reported there was not a similar central funding program for their research. Some researchers were funded by pooling together funding from a variety of sources such as the Department of Energy (DOE), related research foundations, and coalitions like the DOE's Clean Cities coalition. Others had their research funded through partnerships with the automotive industry.

In terms of transportation data, the presentation covered existing and archived supply and demand data. None of the non-transportation attendees expressed interest in the supply-side data. Most were familiar with the Secure Data Center at NREL. One researcher had tried to use the University of Minnesota archives, with "frustrating results" (broken links) and dead ends with regard to obtaining meta-data documentation from the donating agency.

The most interesting discussion centered around a Venn diagram showing the intersection between vehicle-based research, infrastructure (utility) research, and understanding the traveler. Most agreed that their work overlapped in at least two of the listed areas, if not all three. The following highlights the research topics currently undertaken by the attendees:

- They focus on EV performance and gauging early adopter behavior rather than looking into the integrated usage of other non-EV vehicles in the household.

- They focus more on charging behavior of early adopters within the EV project.

- Some attendees mentioned performing the research entirely by themselves with little to no collaboration with others, including limited or no interest in the data needs of other stakeholders.

- They perform research that looks at the current state of adoption and its impact on the electric grid, rather than forecast the future based on current consumption levels.

- There was interest in data to represent a diversity of interests:
  - how behavior changes with the new EV;
  - how customers decide what vehicle to drive; and
  - if replacing a car, why and what factors influence the next car acquired.

### 6.3 Data Commonalities

The focus of this presentation was the data commonalities matrix shown in Table 1. Data needs were broadly classified into four key areas including socio-demographics, travel behavior and vehicle ownership and use, charging behavior, and attitudes toward EV adoption. Some frustration at the lack of available data was expressed. Primarily owing to the fact that the EV market is very nascent, limited revealed-preference data sources exist, and most consumer behavior is captured through stated intentions. The group generally agreed with the key variables included in the matrix. Some additional variables of interest to the group included:

- parking opportunities at home and non-home locations;

- property values;

- inferring locations automatically from GPS data;

- charging behavior—current data provide station-level information, and vehicle-level data are of more interest;

- ambient temperatures associated with vehicle usage;

- vehicle climate control settings; and
- land use and geography of the area, including terrain.

### 6.4 Collaboration Levels

Drawing from different collaboration theories, the presentation then focused on possible collaboration levels. These were presented to the attendees as a straw man to prompt a discussion of current collaboration efforts and what might be reasonable to target. The levels were presented in a four-tiered pyramid.

The lowest level was simple communication including background information about projects, informal networking, and information sharing (similar to these stakeholder meetings). This level could include characteristics such as starting the conversation, getting to know each other and what work is being done, and determining which data are needed/collected. This level might also consist of sharing information about available data sets.

The second level was coordination, defined as more formal coordination at the association level (like the Transportation Research Board, Society of Automotive Engineers, etc.) This would allow a structured dissemination of current discussions, shared interest in research needs, and collaboration on priorities to help everyone move forward with research in this area.

Next was cooperation, which could entail expanding research topics or including project add-ons. A good understanding of data needs and adjusting study designs to obtain data to support others' research (with some type of compensation) would fall under this category.

Finally, the top level was full collaboration, which would include sitting at the table together and identifying data needs, co-ownership of the projects, and resulting data.

Most attendees felt that we are at or approaching the communication phase. In addition, there was much discussion about the lack of a common venue to meet—the lack of an affiliation to bring the players to the table. The Plug-In 2012 conference was one possibility, but very few of the workshop participants were planning to attend that conference, and no other common conference was mentioned.

There was also some discussion about the inability to share data. Those who work with the automotive industry and some government agencies sign nondisclosure agreements and can only release data in an aggregate form. However, one attendee (from Microsoft) gave everyone a link to their choice data set. In this data set, home location was obscured for confidentiality reasons, but their study participants had no problems sharing their GPS data publicly.

### 6.5 Identification of Priorities

The greatest barriers to moving beyond the communication level were mostly institutional in nature, particularly when dealing with private-sector companies. The detailed benefits of collaboration need to be identified.

Equal to the existence of institutional barriers was the lack of a forum to meet and discuss research, research needs, and common goals. Something similar to regional councils is needed

here. All attendees agreed that there is a need to come together in principal, but no mechanism is in place to help connect or establish communication channels to connect researchers.

Finally, the top three issues also considered the lack of funding. As mentioned earlier, the non-transportation researchers pool funding from a variety of sources with varying levels of data disclosure rules. Outside of NCHRP, no formal funding program exists, and without an established forum, it is difficult to identify research needs.

### 6.6 Final Comments

In closing, the attendees were appreciative of the opportunity to meet and share their thoughts. They felt that the preliminary research was on target, and they were supportive of a larger effort to help build connectivity among this fast-growing research community.

## 7.0 CONCLUSIONS

This report summarizes the key findings from Tasks 1 and 2 of the study. It reviews the relevant literature, details the stakeholder interviews and meetings, and discusses the implications of these efforts.

The literature review collected the necessary background information and laid the theoretical foundations that enabled the research team to engage in stakeholder interviews and meetings. The stakeholder interviews clarified the research details and obtained insight into the process, research objectives, and other salient factors like market characteristics. The stakeholder meetings discussed data commonalities and collaboration levels, and identified priorities.

The NCHRP 08-36C Task 108 project evaluated the extent to which travel behavior data would be useful in supporting this type of research, and identified the possibilities for and barriers to collaboration. The research found that collaboration across different stakeholder groups could result in an efficient use of research funding through sharing data, combining and prioritizing research efforts, and disseminating results. The findings also suggest that stakeholders could benefit from collaborations that reduce the net spending of each group on data collection. In turn, the fine-grain details collected as part of these efforts could support the development of advanced analytical approaches for all stakeholders.

The groups both identified the starting point for collaboration as increased communication. This could be as simple as discussing available data sets during informal networking at events. Venues might include Plug-In 2013 or similar EV-focused events. More formal coordination can take place through events coordinated by the Transportation Research Board, the Society of Automotive Engineers, and similar associations. Through improved communications, it may be possible to explore common research needs and share in the design and funding of joint data collection projects. As part of these discussions, institutional barriers and pooled funding opportunities can be explored.

As these collaborative efforts evolve, the hope is that these discussions and efforts will lead to the identification of research topics that would be suitable for funding under future NCHRP programs or other similar sources. Such topics might include:

- the use of technology to document travel behavior patterns and vehicle usage patterns;
- determining the typical spatial geography that might define typical travel, what is longer-distance travel, and how to define and document differences in the two;
- how to best capture and document consumer attitudes regarding recharging, range anxiety, and other EV-related details; and
- eventually conducting a pilot study designed and possibly funded by multiple stakeholder groups.

Moving forward, this research is intended to provide background details and insights to further discussions and collaboration among stakeholder groups. Potential venues for presentation of this research and continuation of the discussions include:

- annual meetings and specialty conferences for trade associations such as the Transportation Research Board, the Society of Automotive Engineers, and similar groups; and

- Plug-In conferences and related EV trade conferences.

Ultimately, establishing contacts and providing communication opportunities will help to identify areas of shared research interest, research opportunities, and potential collaboration.

## 8.0 SUPPORTING MATERIAL

In this section, the background materials used to provide a summary of key data needs and points of intersection across these stakeholder groups is presented. This includes:

- A project bibliography and summaries of that literature as they relate to this topic,
- Interview guide,
- Interview notes,
- Stakeholder workshop discussion guide, and
- Stakeholder workshop minutes.

### 8.1 Literature

In conducting this research, the team assembled a library of literature references. These are presented in this section in two formats. First, a formal project bibliography is listed. This is followed by short abstracts of the literature, organized by key stakeholder group.

#### 8.1.1 Project Bibliography


"Ansi Electric Vehicles Standards Panel Seeks Participants to Develop Standardization Roadmap for Safe, Mass Deployment of Electric Vehicles in the United States." *Information Technology Newsweekly* (2011). Print.

"Better Place: Simply 'Plugging in' One Million Electric Cars Could Add $750 Million in Annual Wholesale Energy Costs Unless 'Smart Charging' Is Adopted, Study Shows." *Energy & Ecology Business* (2011). Print.

"General Motors to Launch First Real-World Smart Grid Pilot." *Computers, Networks and Communications*2011. Print.

"Researchers Use Wireless Technology to Speed Transition to Electric Vehicles." *UCLA Today* (2011). Print.

"Utilities, EV Makers Learn to Cooperate." *Automotive News*. Detroit, MI2011. Print.

"Watts the Deal with Lithium-Ion Batteries?" *Edmunds* (2009). Print.

Aultman-Hall, Lisa, et al. *Travel Demand and Charging Capacity for Electric Vehicles in Rural States: A Vermont Case Study*. *91st Annual Meeting of the Transportation Research Board*. Washington, D.C., 2012.

Carlson, Richard Barney, Matthew G Shirk, and Benjamin M Geller. "Factors Affecting the Fuel Consumption of Plug-in Hybrid Electric Vehicles." *Fuel Cell* (2010). Print.

Chlond, Bastian, and Martin Kagerbauer. *Market Potential for Electric Vehicles from a Travel Behavior Perspective*. *91st Annual Meeting of the Transportation Research Board*. Washington, D.C., 2012.

Clement-Nyns, K., Edwin Haesen, and Johan Driesen. "The Impact of Charging Plug-in Hybrid Electric Vehicles on a Residential Distribution Grid." *Power Systems, IEEE Transactions on* 25 (2010): 371-80. Print.

Council, National Research. "Transitions to Alternative Transportation Technologies - Plug-in Hybrid Electric Vehicles." (2010). Print.

*Electric Vehicle Infrastructure - a Guide for Local Governments in Washington State*. 2010. Print.

Davies, Jamie, and KS Kurani.*Households' Plug-in Hybrid Electric Vehicle Recharging Behavior: Observed Variation in Households' Use of a 5kwh Blended Phev-Conversion*. *89th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2010.

Elgowainy, Amgad, et al. *Impact of Plug-in Hybrid Electric Vehicle Charging Choices in 2030*. *91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.

Fairley, Peter. "Speed Bumps Ahead for Electric Vehicle Charging." *IEEE Spectrum*2010. 13-14. Print.

Flamm, Bradley J., and Asha Weinstein Agrawal. *Constraints to Green Vehicle Ownership: A Focus Group Study*. *91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.

Gonder, J., et al. *Using GPS Travel Data to Assess the Real World Driving Energy Use of Plug-in Hybrid Electric Vehicles (PHEVs). 86th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2007.

Himelic, Jim B., and Frank Kreith. "Potential Benefits of Plug-in Hybrid Electric Vehicles for Consumers and Electric Power Utilities." *Journal of Energy Resources Technology* 133 (2011): 031001. Print.

*EVs and Electric Utility Meters - a Discussion of Data Requirements and Options for Metering Electric Use by Plug-in Electric Vehicles*. 2012. Print.

*Characterizing Consumers' Interest in and Infrastructure Expectations for Electric Vehicles: Research Design and Survey Results*. 2010. Print.

*Electric Wheels - Plugging into Consumers' Perceptions*. 2011. Print.

Khan, Mobashwir, and Kara M Kockelman. "Predicting the Market Potential of Plug-in Electric Vehicles Using Multiday GPS Data." *Energy Policy* (2012): 1-9. Print.

Kley, Fabian, David Dallinger, and Martin Wietschel. "Optimizing the Charge Profile—Considering User's Driving Profiles." (2010). Print.

Loiselle, Aaron, Jacek Rostkowski, and D Karman. "The Effect of Driving Conditions and Ambient Temperature on Light Duty Gasoline-Electric Hybrid Vehicles (3): Battery Energy." *SAE Technical Paper* (2010). Print.

Markel, T., K. Smith, and A.A. Pesaran. *Improving Petroleum Displacement Potential of PHEVs Using Enhanced Charging Scenarios*. *Presented at EVS-24 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium.* Stavanger, Norway, 2009.

Moran, Kevin, and Brendan Foley. "Digital Maps, Connectivity and Electric Vehicles-Enhancing the Ev/Phev Ownership Experience." *Journal of Passenger Cars - Electronic and Electrical Systems* 3 (2010): 76-83. Print.

Morrow, Kevin. "Testing Activity Plug-in Hybrid Electric Vehicle Charging Infrastructure Review." *Power* (2008). Print.

---. "U . S . Department of Energy Vehicle Technologies Program – Advanced Vehicle Testing Activity Plug-in Hybrid Electric Vehicle Charging Infrastructure Review." *Power*

(2008): 1-40. Print.

Park, Sangjun, et al. *A Study of Potential Benefits of Predictive Eco-Cruise Control Systems*. *91st Transportation Research Board Annual Meeting.* 2012.

Pellon, Michael B., David K. Grover, and Margaret J. Eppstein. *An Agent-Based Model for Estimating Consumer Adoption of Phev Technology*. *89th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2010.

Raykin, Leon, Matthew J Roorda, and Heather L MacLean. "Impacts of Driving Patterns on Tank-to-Wheel Energy Use of Plug-in Hybrid Electric Vehicles." *Transportation Research Part D: Transport and Environment* 17 (2012): 243-50. Print.

Simpson, A. *Cost-Benefit Analysis of Plug-in Hybrid Electric Vehicle Technology*. *Presented at the 22nd International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition (EVS-22).* Yokohama, Japan, 2006.

Smart, John, et al. "Electricity Demand of PHEVs Operated by Private Households and Commercial Fleets: Effects of Driving and Charging Behavior." *Energy* (2010). Print.

Sundstrom, Olle, and Carl Binding. "Planning Electric-Drive Vehicle Charging under Constrained Grid Conditions." *2010 International Conference on Power System Technology* (2010): 1-6. Print.

Tate, ED, MO Harpster, and Peter J. Savagian. "The Electrification of the Automobile: From Conventional Hybrid, to Plug-in Hybrids, to Extended-Range Electric Vehicles." *SAE International Journal of Passenger Cars - Electronic and Electrical Systems* 1 (2009): 156-66. Print.

Tate, E.D., and Peter J. Savagian. "The Co2 Benefits of Electrification: E-Revs, PHEVs and Charging Scenarios." *SAE World Congress* (2009). Print.

*Meet Employee Demand for Electric Vehicle Charging and Energize Green Initiatives at the Workplace*. 2010. Print.

Vyas, Anant D, Danilo J Santini, and Larry R Johnson. *Plug-in Hybrid Electric Vehicles' Potential for Petroleum Use Reduction: Issues Involved in Developing Reliable Estimates by Plug-in Hybrid Electric Vehicles' Potential for Petroleum Use Reduction : Issues Involved in Developing Reliable Estimates*. *88th Annual Meeting of the Transportation Research Board.* 2009.

Weiller, Claire. "Plug-in Hybrid Electric Vehicle Impacts on Hourly Electricity Demand in the United States." *Energy Policy* 39 (2011): 3766-78. Print.

Zhou, Yan, Anant Vyas, and Danilo Santini. *Tracking National Household Vehicle Usage by Type, Age, and Area in Support of Market Assessments for Plug-in Hybrid Electric Vehicles*. *91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.

### 8.1.2 Automotive Literature

Literature Review for: Factors Affecting the Fuel Consumption of Plug-In Hybrid Electric Vehicles (2010). *Richard Carlson, Matthew Shirk, and Benjamin Geller*.

- Stakeholder group + research area focus: *Automotive + Fuel Consumption*
- Relevancy to the project: Observed rather than simulated data provided insight about primary factors affecting fuel consumption.
- Data details: Idaho National Labs+AVTA collected data on 294 observed PHEVs over 26 U.S states, Canada and Finland
- Insights into the stakeholder group: Factors affecting fuel consumption are usable electrical energy (battery capacity, depletion rate and state of charge), ambient temperature, engine startup, route type, driver aggressiveness and vehicle accessories.
- Possible issues to consider for this stakeholder group:
  - Battery capacity
  - Depletion rate of charge
  - Ambient temperature
  - Route type
  - Driver aggressiveness
  - Vehicle accessories
- Names of national expert in field of expertise (to build references to contact on interviews): Idaho National Labs (INL): Richard Carlson, Matthew Shirk, and Benjamin Geller.

Literature Review for: Watts the Deal With Lithium-Ion Batteries? (2007). *Edmunds.com*

- Stakeholder group + research area focus: *Automotive + Battery type*
- Relevancy to the project: This article presents the pros and cons of lithium ion batteries.
- Data details: No data. Only the qualitative aspects are presented
- Insights into the stakeholder group:
  - Lithium batteries have a higher density and have the potential to be less expensive in comparison to the other type of batteries.
  - Lithium is less toxic and therefore has less of an impact on environment.
- Possible issues to consider for this stakeholder group:
  - Safety is a primary concern
- Names of national expert in field of expertise (to build references to contact on interviews): www.edmunds.com

Literature Review for: Characterizing Consumers' Interest in and Infrastructure Expectations for Electric Vehicles: Research Design and Survey Results. (2010). *EPRI*

- Stakeholder group + research area focus: *Automotive + Consumer Preference*
- Relevancy to the project: This article looks at consumer expectations regarding PHEV adoption and provides insight towards driving and charging behavior.
- Data details: Data collected in collaboration with SCE.
- Insights into the stakeholder group:
  - Key barriers to adoption include: charging capability, purchase cost and range of vehicle, safety issues, charging time, size/performance misconceptions

- Names of national expert in field of expertise (to build references to contact on interviews): Bernie Neenan (EPRI).

Literature Review for: Using GPS Travel Data to Assess the Real-World Driving Energy Use of Plug-In Hybrid Electric Vehicles (PHEVs) (2007). *J. Gonder, T. Markel, A. Simpson and M. Thornton*

- Stakeholder group + research area focus: *Automotive + Single day GPS data about driving behavior*
- Relevancy to the project: Driving profiles help analyze the performance of advanced PHEVs
- Data details: The study collects 24-hour, second-by-second driving profiles for a single day from a set of 227 GPS instrumented vehicles in St. Louis.
- Suggestions for additional data/information to further the study: Driving profiles over hundreds of real-world drive cycles can be helpful.
- Details regarding use of data: Need to ask authors if data is available for public use
- Insights into the stakeholder group:
  - Around 5% of the vehicles traveled over 100 miles in a single trip.
  - Driving behavior relates to vehicle design, rate of acceleration and speed.
  - PHEV-20 reduced fuel consumption by 55% and PHEV-40 by 66% in comparison to regular vehicles.
- Possible issues to consider for this stakeholder group:
  - PHEV range
  - Driver profile
- Names of national expert in field of expertise (to build references to contact on interviews): Tony Markel (NREL).

Literature Review for: Predicting the Market Potential of Plug-in Electric Vehicles Using Multiday GPS Data (2012). *M. Khan and K. Kockelman*

- Stakeholder group + research area focus: *Automotive + GPS data over a one-year period about driving behavior*
- Relevancy to the project: Driving profiles help analyze the percentage of driving days where electric range will be enough for travel.
- Data details: This study uses Puget Sound Regional Council's 2007 GPS data across 264 households (445 vehicles) and their driving behavior over a period of 1 year.
- Suggestions for additional data/information to further the study: Household demographics and vehicle locations are not available due to privacy concerns.
- Insights into the stakeholder group:
  - Multiple vehicle and multi-day GPS data very helpful to understand the appropriate electric range required in PEVs/BEVs.
- Possible issues to consider for this stakeholder group:
  - Trip length and durations for every vehicle over a one-year period.

Literature Review for: The Effect of Driving Conditions and Ambient Temperature on Light Duty Gasoline-electric Hybrid Vehicles (3): Battery Energy (2010). *Aaron Loiselle, J. Rostkowski, D. Karman and L. Graham.*

- Stakeholder group + research area focus: *Automotive + Battery*
- Relevancy to the project: The study provides insight into the dependence of gasoline-electric hybrid vehicle energies on driving conditions and ambient temperature
- Data details: Tests were done at the Emissions Research and Measurement Section in Ottawa, Canada between -18 deg c and 20 degrees C for different drive cycles.
- Insights into the stakeholder group:
  - Ambient temperature affects regenerative braking energy, battery discharge and charging energy.
- Possible issues to consider for this stakeholder group:
  - Type of battery affects charge/discharge power.
- Names of national expert in field of expertise (to build references to contact on interviews): Tony Markel (NREL).

Literature Review for: Improving Petroleum Displacement Potential of PHEVs Using Enhanced Charging Scenarios (2009). *Tony Markel, Kandler Smith and Ahmad Pesaran.*

- Stakeholder group + research area focus: *Automotive + Fuel Savings + Time of Day+ Battery*
- Relevancy to the project: The study employs three modeling and data resources (rela-world driving profiles, energy storage sizing and fleet charging strategies) to evaluate two PHEV scenarios.
- Data details: Driving profile database comes from 227 unique vehicles GPS logs in St. Louis in 2002 and NHTS 2001 database to assess PHEV suitability for consumers.
- Suggestions for additional data/information to further the study: Not mentioned in the paper.
- Details regarding use of data: Need to ask authors if data is available for public use
- Insights into the stakeholder group:
  - PHEV-20 with opportunity charging during the day would reduce fuel consumption by 71% relative to a conventional vehicle.
  - PHEV-40 with only night charging would reduce fuel consumption by 66% relative to a conventional vehicle.
  - PHEV-20 with lower battery costs shows that charging more frequently could reduce life of battery
- Possible issues to consider for this stakeholder group:
  - PHEV range
  - Driver profile
  - Time of day-charging
- Names of national expert in field of expertise (to build references to contact on interviews): Tony Markel (NREL).

Literature Review for: Digital Maps, Connectivity and Electric Vehicles -Enhancing the EV/PHEV Ownership Experience (2010). *Kevin Moran, Brendan Foley, Ulrich Fastenrath and Jeff Raimo NAVTEQ*

- Stakeholder group + research area focus: *Automotive+ EV experience and driver assistance systems*
- Relevancy to the project: This paper illustrates the importance of topography and shows the importance of integrating intelligent systems in automobiles.
- Data details: Case study related data
- Suggestions for additional data/information to further the study: real time signal cycles, temporary bottlenecks, O-D traffic flow.
- Details regarding use of data: Results indicate that everyday navigation, eco-routing, predictive cruise control affect efficiency and EV experience.
- Insights into the stakeholder group: Intelligent applications and driver assistance systems help to enhance EV ownership experience and demonstrate energy savings.
- Possible issues to consider for this stakeholder group:
  - Integrating driver assistance systems in automobiles
  - Obtaining GPS data for topographies
- Other key reference listed in the article or document that might be of benefit.
  - Electric Vehicle Charging Equipment, Pike Research, May 2010
- Names of national expert in field of expertise (to build references to contact on interviews): NAVTEQ- Kevin Moran (Kevin.moran@navteq.com)

Literature Review for: Plug-in Hybrid Electric Vehicle Charging Infrastructure Review. (2008). *K. Morrow, D. Karner and J. Francfort*. DOE

- Stakeholder group + research area focus: ***Automotive + Battery + Charging***
- Relevancy to the project: This report analyzes the infrastructure requirements and costs associated classified by home type, charging scenario and PHEV battery type.
- Data details: 2001 NHTS data + driving and charging trends of early PHEV adopters
- Insights into the stakeholder group:
  - Low percentage of charge events is due to lack of infrastructure and hence a low monthly average of 50 mpg.
  - Residential, apartment complex and commercial charging stations were tested.
  - Residential garage charging with level 1 charger would cost $878 and with a level 2 charger would cost $2,146.
  - Apartment complex charging with level 1charger would cost $833 and with a level 2 charger would cost $1,520.
  - Commercial facility level 2 charger would cost $1,852.
  - Charging time varies by battery size and type of charging available.
- Possible issues to consider for this stakeholder group:
  - Battery size
  - Type of charger
  - Costs associated with choices made
- Other key reference listed in the article or document that might be of benefit.
- Names of national expert in field of expertise (to build references to contact on interviews): DOE, INL.

Literature Review for: A Study of Potential Benefits of Predictive Eco-Cruise Control Systems (2012). *Sangjun Park et al*

- Stakeholder group + research area focus: ***Automotive +cruise control for fuel efficiency***
- Relevancy to the project: Eco cruise control algorithms and topography prediction demonstrate energy savings.
- Data details: Case study related data
- Details regarding use of data: Researchers suggest collecting more field data using their method in order to validate findings
- Insights into the stakeholder group: This study focuses on attaining energy savings by the use of eco-cruise algorithms.
- Possible issues to consider for this stakeholder group:
  - Improved cruise control algorithms

Literature Review for: Cost-Benefit Analysis of Plug-In Hybrid Electric Vehicle Technology. (2006). *A. Simpson*.

- Stakeholder group + research area focus: *Automotive + Battery + Pricing*
- Relevancy to the project: This study presents a comparison of vehicle purchase costs along with fuel saving benefits in comparison to HEVs and conventional vehicles.
- Data details: This study uses 1995 NPTS data.
- Insights into the stakeholder group:
  - This study evaluates the utility factor for various PHEVs in order to analyze the fraction of miles traveled in the electric mode.
  - Cost benefit depends on a number of factors. These factors include battery costs, fuel costs, vehicle performance and driving habits.
- Possible issues to consider for this stakeholder group:
  - PHEV type
  - Battery size
  - Fuel costs
  - Driving habits
- Names of national expert in field of expertise (to build references to contact on interviews): A. Simpson (NREL).

Literature Review for: Electricity Demand of PHEVs Operated by Private Households and Commercial Fleets: Effects of Driving and Charging Behavior (2010). *John Smart, Jamie Davies, Matthew Shirk, Casey Quinn and Kenneth Kurani*.

- Stakeholder group + research area focus: *Automotive +Electricity Demand Affected by Driving and Charging Behavior*
- Relevancy to the project: Observed rather than simulated data about vehicle driving habits and charging behavior.
- Data details: Idaho National Labs+AVTA collected data on 294 observed PHEVs over 26 U.S states, Canada and Finland

- Insights into the stakeholder group: Factors affecting electricity demand are charging behavior (i.e., where, when and how long drivers choose to charge), driving behavior (i.e., distances between charging events), vehicle and charging infrastructure (battery energy capacity, per-mile electricity consumption and charge rate).
- Possible issues to consider for this stakeholder group:
  - Driving behavior
  - Infrastructure
  - Where, when and how drivers choose to charge
- Other key reference listed in the article or document that might be of benefit.
  Factors Affecting the Fuel Consumption of Plug-In Hybrid Electric Vehicles (2010). Richard Carlson, Matthew Shirk, and Benjamin Geller.
- Names of national expert in field of expertise (to build references to contact on interviews): Idaho National Labs (INL): John Smart, Matthew Shirk and Casey Quinn

Literature Review for: The CO2 Benefits of Electrification E-REVs, PHEVs and Charging Scenarios. (2009). *Tate, E. D., and P.J. Savagian*

- Stakeholder group + research area focus: *Automotive +Type of Electric Vehicle + Grid Impacts*
- Relevancy to the project: This study analytically evaluates the gasoline displacement and Co2 displacement and grid impacts of various vehicle technologies
- Data details: This study uses 2001 NPTS data, time series data from regional travel survey in SCAG
- Insights into the stakeholder group:
  - E-REVs are ten times as likely to finish daily travel in comparison to a BEV and a PHEV.
- Possible issues to consider for this stakeholder group:
  - Fuel economy
  - Battery size
  - Power train
  - Charger efficiency
  - Charging time and where charging occurs
- Names of national expert in field of expertise (to build references to contact on interviews): Ed Tate (GM).

Literature Review for: The Electrification of the Automobile: From Conventional Hybrid, to Plug-in Hybrids, to Extended-Range Electric Vehicles. (2008). *Tate, E. D., M.O. Harpster, and P.J. Savagian*

- Stakeholder group + research area focus: *Automotive +Type of Electric Vehicle*
- Relevancy to the project: This study analytically evaluates the benefit of fuel savings, reduced emissions and energy diversification from vehicle electrification
- Data details: This study uses 2001 NPTS data, time series data from regional travel survey in SCAG and EPA's testing cycles.
- Insights into the stakeholder group:

    - E-REVs are ten times as likely to finish daily travel in comparison to a BEV and a PHEV.
- Possible issues to consider for this stakeholder group:
    - Speed, acceleration, power and energy constraints affect performance.
    - Range anxiety is one of the biggest hurdles that makes owners worry about being stranded without any charge.
- Names of national expert in field of expertise (to build references to contact on interviews): Ed Tate (GM).

Literature Review for: Plug-In Hybrid Electric Vehicles' Potential for Petroleum Use Reduction: Issues Involved in Developing Reliable Estimates. (2009). *A. Vyas, D. Santini and L. Johnson*

- Stakeholder group + research area focus: *Automotive + Fuel Reduction + Charging Ability*
- Relevancy to the project: This paper looks at the number of miles that can be transferred to electricity. In addition, the study evaluates the potential for multiple PHEV battery pack charges per day and also the availability of garages and carports for allowing at-home charging.
- Data details: Travel day data from 2001 and 2005 American Housing Survey are analyzed.
- Suggestions for additional data/information to further the study: None
- Insights into the stakeholder group:
    - PHEV range between 10 and 20 miles would be superior to a range between 30 and 40 miles.
    - Multiple CD range values could help customers meet their potential needs.
- Possible issues to consider for this stakeholder group:
    - Trip lengths
    - Work location
    - Time of day charging
    - Availability of ports
- Names of national expert in field of expertise (to build references to contact on interviews): Anant Vyas and Dan Santini (ANL).

Literature Review for: Tracking National Household Vehicle Usage by Type, Age, and Area in 3 Support of Market Assessments for Plug-in Hybrid Electric Vehicles. (2012). *Y. Zhou, A. Vyas and D. Santini*

- Stakeholder group + research area focus: *Automotive + Vehicle Type + Usage*
- Relevancy to the project: This study analyzes the vehicle use and non-use by vehicle type, vehicle age and area type. It provides insight regarding the most utilized vehicle type that can be considered for new-vehicle technologies.
- Data details: 2009 NHTS data
- Suggestions for additional data/information to further the study: None
- Insights into the stakeholder group:
    - Most of the vehicles that were not used were left at home because household members owned other vehicles that they used or rode with others.
    - Vehicle use increases within MSAs in comparison to non-MSAs.

    - Usage also drops from 68% for the <=10 years age vehicles to 50% for the >10 years age vehicles.
    - SUVs and vans are the most-frequently used vehicles.
- Possible issues to consider for this stakeholder group:
    - Vehicle type that is frequently used.
    - Residential location
    - Vehicle age
    - Travel day
- Names of national expert in field of expertise (to build references to contact on interviews): Anant Vyas and Danilo Santini (ANL).

### 8.1.3 Utility Industry Studies

Literature Review for: ANSI Electric Vehicles Standards Panel Seeks Participants to Develop Standardization Roadmap for Safe, Mass Deployment of Electric Vehicles in the United States, *Anonymous*, Information and Technology Newsweekly, May 17, 2011 , Page: 73

- Stakeholder group + research area focus : Utility – Auto Industry – Government + Cooperation – Coordination – Standardization
- Relevancy to the project: ANSI has formed the Electric Vehicles Standards Panel (EVSP) to bring together individuals from the auto industry, utility industry and the government to facilitate the large scale introduction of EV into the market. The EVSP will facilitate communication among panel members.
- Other relevant information for study: It may be beneficial to contact a member of the EVSP to identify what they have done and what data elements their panel members see as pertinent. Ideally this group may have already accomplished a lot of the things we are going after.

Literature Review for: Automotive; General Motors to Launch First Real-World Smart Grid Pilot, *Anonymous*, Journal: Computers, Networks & Communications, August 4, 2011

- Stakeholder group + research area focus : Utility – Auto + Smart grid -- Smart charging
- Relevancy to the project: General Motors, OnStar and Raleigh, NC regional utilities teamed up on a pilot project that will facilitate data transfer from OnStar enabled Chevy Volts driven by utility employees to public utilities. Data elements include charge levels, charge locations, and charge time.
- Data details
    - Specific data elements if available: EV charge level – charge location – charge time
    - Level of geographic specificity: Raleigh, NC region
    - Type of data w/details (If GPS, what is the recording interval): data will be collected wirelessly using the OnStar Advanced Telematics Operations Management System (ATOMS) without the EV having to “hook up” to a charging station.
- Details regarding use of data: These data will be used to help utilities understand habits of EV drivers, predict demand, establish charging rates and locate charging stations. The data will also be used to establish and evaluate Smart grid programs, such as the utility communicating with the EV driver and providing real time updates of charging rates by

time of day (demand pricing for EV . . . to reduce the likelihood of overburdening the system during peak times of energy use).

- Names of national expert in field of expertise (to build references to contact on interviews): Nick Pudar, OnStar VP of Planning and Business Development
- Other relevant information for study: This project sounds strikingly similar to one being launched by Austin Energy. It may be beneficial to contact AE to identify more information regarding how these data will be used or what other elements are being collected.

Literature Review for: Better Place: Simply "Plugging In" One Million Electric Cars Could Add $750 Million in Annual Wholesale Energy Costs Unless "Smart Charging" is Adopted, Study Shows, *Anonymous*, Energy & Ecology Business, July 29, 2011, p. 33.

- Stakeholder group + research area focus : Utility – Managed Charging
- Relevancy to the project: Most EV drivers want to be able to plug in according to their individual needs, but unmanaged charging on a large scale will everyone . . .the EV driver and the utility. Managed charging (demand pricing) can result in cost savings and improved grid stability, without impairing the charging needs of the EV drivers.
- Data details
  - Specific data elements if available: no variables discussed
  - Level of geographic specificity: Greater Washington-Baltimore region
  - Type of data w/details (If GPS, what is the recording interval): no data details
- Suggestions for additional data/information to further the study: White paper available at http://btrp.lc./fXd.
- Insights into the stakeholder group: Utility believe that the concept of "managed charging" (demand pricing of electricity) will lead to a win-win situation, offering grid stability to the utility and its customers and cost savings to EV owners.
- Possible issues to consider for this stakeholder group: will EV owners buy into this concept, given that they are sacrificing convenience for cost savings?
- Names of national expert in field of expertise (to build references to contact on interviews): Hugh McDermott, VP of Utility and Smart Grid Alliances at Better Place; Chantal Hendrzak, Director of Applied Solutions at PJM Interconnect; Sam Jaffe, Research Manager at IDC Energy Insights; Robbie Diamond, President/CEO of the Electrification Coalition.

Literature Review for: Electric Wheels-Plugging into Consumers' Perceptions, *Anonymous*, EPRI Journal, Winter 2011, Page: 15

- Stakeholder group + research area focus : Utility + Data Needs
- Relevancy to the project: EPRI has long sought out to identify how EVs will affect the grid. In 2009 EPRI conducted an online survey to evaluate EV consumer perceptions in the Southern California Edison service area. This was followed up with a similar study in 2010 in the Southern Company service area (Atlanta) and again in Tennessee TVA with a survey of 1,000 respondents. There were similarities across the board, but CA seemed to differ from GA/TN in a few key areas. CA respondents much more likely to buy an EV in the

next five years. CA respondents much more likely to buy into the idea of managed charging.

- Data details
  - Specific data elements if available: Consumer charging preferences; accessibility of at home charging; at home charging plan preferences; interest in buying an EV; influence of three factors on EV purchase: gas prices, vehicle price, consumer friends and family; willingness to pay for charging options.
  - Level of geographic specificity: utility service area
  - Type of data w/details (If GPS, what is the recording interval):
- Details regarding use of data: Goals of the effort are to establish a national database that can be queried to answer research questions. The database will provide a historic perspective: early adoption vs. established experienced consumers; estimate an adoption curve; estimate vehicle demand; estimate willingness to pay for EVs; willingness to pay for EV charging options; estimate how EVs will change the demand for electricity; estimate how regional and cultural differences affect EV consumer choice; estimate what EV owners expect of their utility;
- Insights into the stakeholder group: EPRI appears to be a very good organization for inclusion in any type of panel discussion on this topic. Their website is also a tremendous source for EV related information.
- Possible issues to consider for this stakeholder group: Consumers may not understand the jargon used by the automotive and utility industry. Regional and cultural differences affect EV consume attitudes. Consumers may not be willing to pay much for quicker charging options.
- Names of national expert in field of expertise (to build references to contact on interviews): Mark Duvall, Director of the Electric Transportation Program at EPRI; Bernard Neenan, Technical Executive at EPRI.
- Other relevant information for study: Pre-study focus groups conducted by EPRI suggest that public does not understand industry nomenclature. Don't know the difference between EV and hybrid . . .they see them as the same thing

Literature Review for: Utilities, EV Makers Learn to Cooperate, ***Anonymous***, Automotive News, Volume: 85, Issue 6477, August 15, 2011 , Page: 6

- Stakeholder group + research area focus : Utility – Auto Industry + Cooperation -- Standardization
- Relevancy to the project: Utilities maximize their systems for their own area. It is critical to understand how EV owners in their service area will impact the system. Utilities and EV manufacturers have many differences but the one similarity is the customer. Consumer education will be critical in meeting the goals of both auto industry and utility industry.
- Names of national expert in field of expertise (to build references to contact on interviews): Charlie Allcock, Director of Economic Development at Portland General Electric; Ed Kjaer, Director of Plug in Vehicle Readiness at Southern California Edison.

Literature Review for: Utilities, EV Makers Learn to Cooperate, ***Anonymous***, Automotive News, Volume: 85, Issue 6477, August 15, 2011 , Page: 6

- Stakeholder group + research area focus : Utility – Auto Industry + Cooperation -- Standardization
- Relevancy to the project: Utilities maximize their systems for their own area. It is critical to understand how EV owners in their service area will impact the system. Utilities and EV manufacturers have many differences but the one similarity is the customer. Consumer education will be critical in meeting the goals of both auto industry and utility industry.
- Names of national expert in field of expertise (to build references to contact on interviews): Charlie Allcock, Director of Economic Development at Portland General Electric; Ed Kjaer, Director of Plug in Vehicle Readiness at Southern California Edison.

Literature Review for: Meet Employee Demand for Electric Vehicle Charging and Energize Green Initiatives at the Workplace – ChargePoint Network Electric Vehicle Charging Infrastructure, March 2010, *Coulomb Technologies*, p. 1-5)

- Stakeholder group + research area focus : Utility – Smart Grid
- Relevancy to the project: The majority of this article focuses on the technology and infrastructure that may help employers trying to encourage the use of EVs by their employees, such as installing charging stations at work (even though the majority of charging would be expected to be done at home). Insight related to how utility companies may be affected by these efforts are provided, suggesting that, "With the time-variable nature of renewable energy sources and with anticipated increase in electrical demand, utility companies are implementing Smart Grid capabilities to ensure reliable energy delivery during peak load times within their service area (p. 3)."
- Data details
  - Specific data elements if available: To support smart grid technologies, utility companies would need access to data collected through charging stations. The article suggests that, "To leverage future utility Smart Grid energy incentives, charging station should support Advanced Metering Infrastructure (AMI), demand response program, and time-of-use (TOU) pricing (p. 3)."
  - Level of geographic specificity: General
  - Type of data w/details (If GPS, what is the recording interval)?
- Details regarding use of data: Data would support smart grid applications
- Possible issues to consider for this stakeholder group: How can utilities coordinated with vendors, businesses, and employees in addressing a wide variety of needs related to EVs?

Literature Review for: Electric Vehicle Infrastructure -- A Guide for Local Governments in Washington State – Model Ordinance, Model Development Regulations, and Guidance Related to Electric Vehicle Infrastructure and Batteries per RCW 47.80.090 and 43.31.970 – Appendices, *Department of Commerce, Puget Sound Regional Council, Technical Advisory Committee, Consultant Team*, July 2010

- Stakeholder group + research area focus : utility + expert contacts
- Relevancy to the project: This document is being included in the literature review, because it contains a database of expert contacts and their corresponding organizations. It also contains a structured interview guide that may be of benefit in compiling the guide for this project.

- Other key reference listed in the article or document that might be of benefit: contacts
- Names of national expert in field of expertise (to build references to contact on interviews): There are too many to list here. See referenced document.

Literature Review for: Speed Bumps Ahead for Electric-Vehicle Charging: Plugging in cars, even overnight, will strain local grids and could boost pollution, *Peter Fairley*, IEEE Spectrum, January 2010, p. 13-14

- Stakeholder group + research area focus : Utility-EV Charging
- Relevancy to the project: This article addresses some of the concerns that utilities may face—specifically in California—as the number of electric vehicles increase and vehicles are charged at night. Generally, night hours are used as a cool down time for the transformers, so equipment may be overloaded if this cool down time is not provided.
- Data details
  - Specific data elements if available:
  - Californians buy 24% of EV in US
  - Based on California rules, large automakers required to "sell 20,000 more [EV] annually starting in 2012"
  - "For their part, regulators at the California Air Resources Board predict that a kilometer's worth of EV Charge should result, on average, in just 43 percent as much carbon dioxide as burning a kilometer's worth of gasoline."
  - Level of geographic specificity: California
  - Type of data w/details (If GPS, what is the recording interval)?
- Insights into the stakeholder group: Insights included from multiple utilities. How would different utility companies work together in addressing issue related to EV?
- Names of national expert in field of expertise (to build references to contact on interviews).
  - Saul Zambrano, director for clean air and transportation at San Francisco-based Pacific Gas & Electric Co.
  - Doug Kim, director of EV readiness efforts at Rosemead, California-based Southern California Edison (SCE)
- Other relevant information for study: "California's regulators also envision smart charging to help EVs synchronize with the state's wind farms, which tend to provided most of their energy overnight (p. 14)."

Potential Benefit of Plug In Hybrid Electric Vehicles for Consumers and Electric Power Utilities, ***Kreith, Frank ; Himelic, Jim B.,*** Journal: Journal of Energy Resources Technology-Transactions of the ASME, September 2011, Volume: 133, Issue: 3, Page: 73; URL: http://dx.doi.org/10.1115/1.4004151

- Stakeholder group + research area focus : Utility + Smart charging – System optimization – Benefit of off peak PHEV charging
- Relevancy to the project: This article seeks to determine the net benefit of PHEVs taking into account the consumer and utility perspective. Information used by the utility to determine cost of PHEV charging include: size of PHEV fleet plugging into the grid, type of vehicle (charge rate (can be determined by voltage of outlet plugged into), charge capacity, etc.), time of day of charge, recharge frequency (in terms of time between

recharges and miles between recharges), driving profile (hwy vs. urban driving, driver habits (aggressive vs. passive). From the utility perspective . . . "the deployment of PHEVs would increase the utilization of existing infrastructure by improving the load profile if the charging of the vehicle is restricted to off-peak periods. Thus no additional transmission and distribution infrastructure is required . . . and no additional generation facilities are required . . . The net carbon emission for the combined electric utility and transportation industry would decrease due to the vehicular emissions being reduced by a greater amount."

- Data details
  - Specific data elements if available: no variables discussed
  - Level of geographic specificity: the data used in this analysis
  - Type of data w/details (If GPS, what is the recording interval): no data details
- Insights into the stakeholder group: The article suggests that PHEVs are a win/win for both consumers and the utility if the charging time is limited to off peak hours.

Literature Review for: Researchers use wireless technology to speed transition to electric vehicles, UCLA Today, *Judy Lin* Faculty and Staff News, http://today.ucla.edu/portal/ut/PRN-rajit-gadh-electric-vehicle-research-211170.aspx, July 27, 2011

- Stakeholder group + research area focus : Utility – Smart Grid and potential simulation research
- Relevancy to the project: This article details some of the research related to EVs that is being done at the UCLA Smart Grid Energy Research Center (SMERC). One of the areas that researchers at this lab are working to address is how to deal with a potential overload in demand for electricity. To address this concern they are considering creating charging systems that control when vehicles are charged to ensure that there is not too much power demand all at once. Additionally, researchers are considering the potential for EVs to actually give power back to the system when needed, acting as a power reserve. Researchers at SMERC plan to "do some simulations and see how the EVs will behave, how people will behave and how the utilities will behave."
- Details regarding use of data: The SMERC lab is collecting data on EV batteries that are stored in computers and available for research related to how EV battery charging could be handled to ensure a smooth transition to increasing EVs and their energy demands.
- Other key reference listed in the article or document that might be of benefit: UCLA Electric Vehicle-Smart Grid (EV-SG) Living Lab Demo and EV-SG Consortium.
- Names of national expert in field of expertise (to build references to contact on interviews). -Engineering Professor Rajit Gadh, director of SMERC at UCLA

Literature Review for: EVs and Electric Utility Meters – A Discussion of Data Requirements and Options for Metering Electric Use by Plug-In Electric Vehicles, ***Regional Electric Vehicle Initiative, REVI Utilities Working Group*** (Northeast Utilities, United Illuminating, CMEEC, National Grid, NSTAR, MMWEC), REVI Discussion Paper, January 2012

- Stakeholder group + research area focus : *[automotive - battery, utility – electricity demand, travel behavior – trip chaining*]

- Relevancy to the project. This article identifies electric utilities as a key stakeholder in considering electric vehicle metering options. Electric companies already meter the use of electricity for purposes other than EVs. Future metering system technologies could be utilized to incorporate the metering of EV use as well. As noted in the article, "Many utilities are testing or implementing 'smart meters' and can offer time-of-use (TOU) rates for customers plus other 'smart grid' capabilities (p. 3)." For the purposes of metering and properly allocating electric rates at different times and locations, it may be helpful for utilities to gather data related to time and amount of charging.
- Data details
  - Specific data elements if available: Issues related to electricity metering, time and amount of use discussed
  - Level of geographic specificity: NA-more general discussion paper
  - Type of data w/details (If GPS, what is the recording interval)?: none
- Details regarding use of data: Metering information could be used to collect and address future EV user fees (similar to the gas tax)
- Insights into the stakeholder group: Different utility companies will have varying degrees of metering technology available to them.
- Possible issues to consider for this stakeholder group: Important to work with other stakeholders in addressing the idea of metering.
- Other key reference listed in the article or document that might be of benefit: -*The Utility Role in Supporting Plug-In Electric Vehicle Charging*, California public Utilities Commission, 2010 / Northeast States Coordinated Air Use Management website (http://www.necscaum.org/topics/low-carbon -fuels)

Literature Review for: Planning Electric-Drive Vehicle Charging under Constrained Grid Conditions, *Olle Sundstrom and Carl Binding*, 2010 International Conference on Power System Technology, 2010 IEEE

- Stakeholder group + research area focus : Utility-EV Charging Schedule Optimization
- Relevancy to the project: Electric utility companies will clearly be interested in optimizing the scheduling of when EVs are charged to ensure that adequate power within a grid is available. To address this issue, several pieces of data will be required, including price elasticity and grid loading. As indicated by the authors, "The goal of the optimization in an unconstrained grid is to derive a charging schedule for each vehicle that ensures sufficient energy for the predicted trips, while, for example, minimizing the total cost of the electricity used for the fleet."
- Details regarding use of data: This research was based on a simulation meant to represent the power grid of the Danish island of Bornholm. The authors simulation model by indicating that, "The parameters for the grid model are constructed using both real-world and synthetic data, where no real-world data is available."
- Suggestions for additional data/information to further the study: The authors suggest several areas of future research. Topics include the level of constraints placed on the grid, varied types of EVs and the location and type of where they charge, and the impact that prediction errors may have on the results.
- Other key reference listed in the article or document that might be of benefit.

[1]-M.M. Collins and G.H. Mader, "The timing of EV recharging and its effect on utilities," *IEEE Transactions on Vehicular Technology,* vol. 32, no. 1, pp. 90-97, 1983
[3]-S.D. Jenskins, J.R. Rossmaier, and M. Ferdowsi, "Utilization and effect of plug-in hybrid electric vehicles in the United State power grid," in *Proceedings of the IEEE Vehicle Power and Propulsion Conference,* Harbin, China, 3-5 September 2008, pp. 1-5.
[14]-S. Letendre and R.A. Watts, "Effects of plug-in hybrid electric vehicles on the Vermont electric transmission system," Presented at the Transportation Research Board Annual Meeting, Washington, C.D., 11-15 January 2009.
[17]-P. Kadurek, C. Ioakimidis, and P. Ferrao, "Electric vehicles and their impact to the electric grid in isolated systems," in *Proceedings of the International Conference on Power Engineering, Energy and Electrical Drives*, Lisbon, Portugal, 18-20 March 2009, pp. 49-54.

Literature Review for: (Reference Information): Plug-in hybrid electric vehicle impacts on hourly electricity demand in the United States, *Claire Weller*, Energy Policy 39 (2011) p. 3766-3378

- Stakeholder group + research area focus : Utility-electricity demand
- Relevancy to the project: This article used data from the 2001 National Household Travel Survey to create a simulation algorithm capable of producing disaggregate data related to electric vehicle charging patterns based on geographic region (i.e. different states, and urban vs. rural), vehicle age, EV voltage level, charge location, and charge time. As noted by the authors, "The distribution of electric load over the different times of the day is critical for utility planning purposes (p. 3770)." Being able to accurately simulate this distribution will contribute towards better planning on the part of utilities.
- Data details
  - Specific data elements if available: Geographic region (charging profile by could drastically differ, i.e. California and New York; urban vs. rural had similar distributions but rural generally had higher demand), vehicle age, EV voltage level, charge location (home, work, commercial), charge time
  - Level of geographic specificity: National 2001 NHTS, but also discussed disaggregation by state and urban vs. rural
  - Type of data w/details (If GPS, what is the recording interval)?
- Suggestions for additional data/information to further the study: The author provides multiple suggestions for future work in this area, including implementing the developed algorithm into software useable by utility companies. Likewise, the author indicates that, "As a next step, the load profile algorithm could be extended to include vehicle=to=grid capabilities for ancillary service and stoppage and to determine a smart charging algorithm based on endogenous market signals (p. 3777)."
- Insights into the stakeholder group: Utilities may need to address "Range Anxiety"—which the author indicates is the fear of PEV drivers that they will not have access to an electric power source and be stranded. Electric utility companies may want to consider what distribution of charging stations is acceptable to adequately address this concern. Additionally, utility companies may want to consider that, "Enabling charging in places other than the home increase the daily energy charged by 24-29% (1.5-2 kWh/day) (p. 3767)."

- Other key reference listed in the article or document that might be of benefit: -US President Obama, B., 2008. The White House Website at http://www.whitehouse.gov/, which discusses the goal to have 1 million PHEVs in America by 2015

### 8.1.4 Travel Behavior Studies

Literature Review for: "Travel Demand and Charging Capacity for Electric Vehicles in Rural States: A Vermont Case Study," *Lisa Aultman-Hall, Justine Sears, Jonathan Dowds and Paul Hines*, TRB 2012 (disk)

- Stakeholder group + research area focus: Utility + Automotive + Travel Behavior
- Relevancy to the project: This study used the penetration of Hybrid vehicles to estimate the location of EV adopters. In addition, the special travel characteristics of rural households and the possible effect on the rural electrical grid were examined.
- Data details: 2009 NHTS (add-on)
- Insights into the stakeholder group:
  - The authors found a geographic clustering of current hybrid vehicles, in both urban and rural areas, suggesting that the distribution of future EVs may also cluster in rural areas.
  - The author's analysis shows that between 69 and 84% of the state's vehicles could be replaced by a 40-mile range EV, depending on the availability of workplace charging.
  - Problematic areas for EV adoption may be suburban areas, where both residential density is high (and potential clustering of hybrids), as well as miles driven.
  - Concludes that EVs are viable for rural mobility demand but require special consideration for power supply and vehicle charging infrastructure.
- Possible issues to consider for this stakeholder group:
  - Early-adopter clustering
  - Rural PHEV special considerations

Literature Review for: "Market Potential for Electric Vehicles from a Travel Behavior Perspective," Institute for Transport Studies Karlsruhe Institute for Technology (KIT), *Bastian Chlond and Martin Kagerbauer*, 2012 TRB (disk)

- Stakeholder group + research area focus: Automotive + Travel Behavior
- Relevancy to the project: This paper looks at the type of households that own vehicles that travel within the PHEV range per day. The authors did not analyze the availability of at-home charging.
- Data details: German Mobility Panel Survey
- Suggestions for additional data/information to further the study: None
- Details regarding use of data: Not applicable
- Insights into the stakeholder group:
  - The authors found that about seven percent of the total fleet could be replaced with electric vehicles with no change to the travel behavior
  - About half of the vehicles that could be replaced were owned by retired persons.
  - They concluded that "car manufacturers should also take this target group into account when marketing their electric vehicles."
- Possible issues to consider for this stakeholder group:
  - Demographic characteristics of low-mileage vehicle owners

Literature Review for: "Travel behaviour of potential electric vehicle drivers. The need for charging and contribution to stabilysing the electric grid," *L Christensen*, DTU Transport, DK, in Proceedings of the European Transport Conference 2010, at: http://www.etcproceedings.org/paper/travel-behaviour-of-potential-electric-vehicle-drivers-the-need-for-charging-a

- Stakeholder group + research area focus: Energy and Environment+ Fleet Characteristics
- Relevancy to the project: This is from a European perspective, and the push for EV is more direct there. The study attempted to answer these questions:
  1) How is travel behavior related to the need for normal or fast battery recharging? How central is charging accessibility to users' willingness to purchase an electric vehicle.
  2) Assessment of the possibility to regulate the charging periods and to use the EVs as storage, which requires drivers to plug in even when the vehicle does not need a charge.
- Data details: A GPS based driving dataset obtained in a road pricing experiment in the Copenhagen area with data for 365 cars in between 13 and 150 days each is used to illustrate the charging needs. The Danish National Travel Survey is used to estimate when and where connection to the grid can take place.
- Suggestions for additional data/information to further the study: None
- Insights into the stakeholder group:
  - The analyses show that if most cars will need to be charged outside of the home within a 2 weeks' period. Approximately 15 % of the cars must perform fast charging within a couple of days and approximately 20 % once a week if they only have a driving range of 80 km. In case of a driving range of 150 km, a maximum of 8 % will have to perform fast charging once a week.
  - This study found that cars could be charged outside of peak electric use periods if the charging is regulated. If the charging is not regulated 56 % of the normal charging of cars will take place in two peak periods per day when other kind of electricity demand is also at maximum. If the charging is fully regulated only 19 % need to take place during the day as normal charging and further 19 % as fast charging
  - In order to take advantage of the storage power of the EV, for example when significant amounts of wind power is introduced to the system, it will be necessary to get the drivers to connect even when they do not need to charge.

Literature Review for: "Transitions to Alternative Transportation Technologies--Plug-in Hybrid Electric Vehicles," TRB Special Report, Authors: *Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies*; National Research Council, Date: 2010 at: http://www.nap.edu/openbook.php?record_id=12826&page=1

- Stakeholder group + research area focus: Energy and Environment+ Fleet Characteristics
- Relevancy to the project: This is a special report by TRB from The Board on Energy and Environmental Systems, part of the National Academies' Division on Engineering and Physical Sciences (DEPS).
- Data details: Broad range of existing lit for policy
- Suggestions for additional data/information to further the study: None
- Details regarding use of data: Not applicable

- Insights into the stakeholder group:
  - Suggests the costs of plug-in hybrid electric cars are high--largely due to their lithium-ion batteries--and unlikely to decrease drastically in the near future.
  - Advised that while a mile driven on electricity is cheaper than one driven on gasoline, it will likely take several decades before the upfront costs decline enough to be offset by lifetime fuel savings.
  - Subsidies in the tens to hundreds of billions of dollars over that period will be needed if plug-ins are to achieve rapid penetration of the U.S. automotive market.
  - Even with these efforts, plug-in hybrid electric vehicles are not expected to significantly impact oil consumption or greenhouse gas emissions before 2030.
- Possible issues to consider for this stakeholder group:
  - Gov't subsidies
  - Other cost off-sets
  - Improved battery technology
- Names of national expert in field of expertise (to build references to contact on interviews): DEPS

Literature Review for: "Households' Plug-in Hybrid Electric Vehicle Recharging Behavior: Observed variation in households' use of a 5kWh blended PHEV-conversion," *Jamie Daviesa and Kenneth S. Kurania*, TRB 2010 (disk)

- Stakeholder group + research area focus: Utility + Automotive + consumer behavior
- Relevancy to the project: Plug-in hybrid electric vehicles (PHEVs) are considered a transitional technology toward fully electric vehicles. This study of PHEV testers in Northern California looked at real charging behavior by forty households that participated in a PHEV demonstration in Northern California.
- Data details: PHEV Demonstration households (40) in NoCal
- Suggestions for additional data/information to further the study: None
- Details regarding use of data:
- Insights into the stakeholder group:
  - The charging behavior generally followed the expected (once a day to full charge) but the distributions are not symmetrical about the mean and there exists a large variation in both the average number of times households plugged-in per day and the average energy per plug-in event.
  - Frequency of recharging is perhaps the daily behavior that most affects the energy, social, and 19 environmental benefits of PHEVs
  - The reported range of behaviors shows that PHEVs success in meeting energy and emissions goals relies on PHEV users' recharging and driving behavior as much or more as on PHEV designs.
  - Interestingly, households reported they lacked a sense of the etiquette that would shape recharging at away-from-home locations. Households who noticed "EV parking" and recharging spaces often asked us whether they could park and charge their PHEVs in such spaces. The few bolder individuals who attempted this discovered that such spaces lacked 110-volt outlets suitable to recharge the PHEVs they were driving. Many households also said they were uncertain of the propriety of asking friends, acquaintances, employers, and business owners if they could plug-in.

- Possible issues to consider for this stakeholder group: Utilities would be interested in charging behavior and possibly cooperate on studies similar to the PHEV demonstration project: There may be interest in the type of 'etiquette' constraints on charging behavior.

Literature Review for "Impact of Plug-in Hybrid Electric Vehicle Charging Choices in 2030," Argonne National Laboratory, *Amgad Elgowainy, Yan Zhou, Anant Vyas, Matthew Mahalik, Dan Santini, and Michael Wang* TRB 2012 (disk)

- Stakeholder group + research area focus: Utility Impact + GHG emissions
- Relevancy to the project: This study systematically examined the impacts of multiple plug-in hybrid electric vehicle (PHEV) recharging scenarios in the western United States (in particular, Western Electricity Coordinating Council, WECC service area) in 2030. The goal of the study is twofold: to examine the impact of PHEV market penetration and charging scenarios on the electric utilities and transmission grid and to estimate the potential reductions in petroleum use and greenhouse gas (GHG) emissions due to PHEV miles traveled mainly on grid electricity.
- Data details: 2009 NHTS data
- Suggestions for additional data/information to further the study: None
- Details regarding use of data: Not applicable
- Insights into the stakeholder group:
  - The authors examined three charging scenarios: (1) PHEVs start recharging upon arrival at home at the end of their last daily trip, (2) PHEVs complete the recharging of their batteries just before the start of the first daily trip, and (3) PHEVs may have additional charging opportunity during daytime.
  - The three charging scenarios produce distinct hourly electric load profiles, with the opportunity charging scenario resulting in a significant increase in load during the daytime.
  - All scenarios resulted in a similar fuel use by the utility to offset the additional demand. A well-to-wheel (WTW) analysis revealed that the marginal generation to sustain the PHEV load produces 45% and 17% less GHG emissions by PHEVs relative to those of conventional gasoline internal combustion engine vehicles (ICEVs) and gasoline hybrid electric vehicles (HEVs), respectively.
- Possible issues to consider for this stakeholder group:
  - Time of day for significant dwell-time of vehicles
  - Location of significant dwell time
  - Utility fuel for added load
- Other key reference listed in the article or document that might be of benefit.
- Names of national expert in field of expertise (to build references to contact on interviews):
  Amgad Elgowainy; Phone: (630) 252-3074; E-mail: aelgowainy@anl.gov
  Anant D. Vyas; Phone: (630) 252-7578; E-mail: avyas@anl.gov

Literature Review for: "Constraints to Green Vehicle Ownership: A Focus Group Study," *Bradley J. Flamm and Asha Weinstein Agrawal,* TRB 2012 (disk)

- Stakeholder group + research area focus: Automotive + Consumer Preference

- Relevancy to the project: This study explores that attitudes-behavior gap as it relates to vehicle purchase decisions, using analysis of focus group sessions conducted in Sacramento, California. The focus group conversations were designed to address three key questions :
  1. To what extent do people perceive that their vehicle ownership reflects their environmental attitudes?
  2. What barriers and constraints do they perceive to aligning their environmental attitudes with their vehicle ownership choices?
  3. What changes in personal circumstances and travel options could permit them to bring their vehicle ownership more closely in line with their environmental attitudes, that is, to purchase "green vehicles" (we use this term to refer to vehicles that are smaller, significantly more fuel efficient and less polluting than most passenger vehicles on the road)?
- Data details: Focus groups in Sacramento, CA.
- Insights into the stakeholder group: The study found that even if the participant had strong environmental concerns their vehicle choices did not reflect that.
  - For the most part family and work responsibilities, residential choices, and their current vehicle attributes all constrained participants' vehicle purchase choices
  - Serious misunderstandings about the environmental impacts of owning and using vehicles also were noted, making it difficult for many to accurately assess their alternatives.
- Possible issues to consider for this stakeholder group: Potential for private-public partnership to create and sustain education/information campaigns to raise awareness about internal combustion engines impact on the environment and alternatives

Literature Review for: Working Paper Sustainability and Innovation No. S 6/2010 "Optimizing the Charge Profile—Considering User's Driving Profiles," Fraunhoffer Institute, *Fabian Kley, David Dallinger, Martin Wietschel*, 2010 at:
http://isi.fraunhofer.de/isi-media/docs/e-x/working-papers-sustainability-and-innovation/WP6-2010_optimizing-charge-profile.pdf?WSESSIONID=jkhlvfbs

- Stakeholder group + research area focus: Automotive + Travel Behavior
- Relevancy to the project: PHEVs are somewhat controversial. On the one hand, the evolutionary approach of a hybrid vehicle helps the consumer to adapt to electric driving, using the range extender when driving longer distances. On the other hand, PHEVs have a more complex propulsion system and a potentially low emission impact due to a low electric driving share. These factors, however, strongly depend on the consumers' driving and charging behavior.
  - This paper simulates realistic driving based on the national German travel survey. Firstly, battery profiles are modeled using further information about parking locations, charging scenarios, as well as different battery sizes. Secondly, total costs of different alternative vehicles are calculated and minimized varying the battery size.
- Data details: German Mobility Panel Study
- Insights into the stakeholder group:
  - According to the simulation, PHEVs with high electric driving shares of more than 80% allow fair emission reductions.

    - As the market share of PHEVs increases the battery size can be customized for different customer segments and vehicle types.
- Possible issues to consider for this stakeholder group:
    - Different customer types and
    - Different vehicle types and use

Literature Review for: "An agent-based model for estimating consumer adoption of PHEV technology," *Michael B. Pellon, David K. Grover, Margaret J. Eppstein* (corresponding) et al., TRB 2010 (disk)

- Stakeholder group + research area focus: Automotive + Consumer Markets + Survey Design
- Relevancy to the project: This study models the adoption of plug-in hybrid vehicle (PHEV) technology under a variety of scenarios. People decide whether or not to buy a PHEV by weighing environmental benefits and financial considerations (based on their personal driving habits, their projections of future gas prices, and how accurately they estimate fuel costs), subject to various social influences. The relevant results indicate that simple web-based tools for helping consumers to more accurately estimate relative fuel costs could dramatically increase PHEV adoption.
- Data details: NHTS 2001
- Insights into the stakeholder group:
    - Significant barriers exist to widespread early adoption of new PHEV technologies: 69% of respondents reported little or no familiarity with PHEV technology , many consumers are hesitant to adopt new technologies before they are tried and tested, and there may be significant consumer uncertainty about potential problems such as battery life and replacement costs, and vehicle recharging time, which would contribute to this hesitancy
    - Programs could be put into place to lower the thresholds at which consumers feel comfortable considering a PHEV, such as warranties on batteries or battery exchange programs that could help to alleviate consumer uncertainties about the lifetime and replacement costs of the PHEV battery packs.
    - There is some indication that social influences are important in decision making. New viral marketing techniques can capitalize on the social diffusion.
- Possible issues to consider for this stakeholder group:
    - Web-based education campaigns
    - Viral marketing
    - Clustered adoption of new technology (utility companies may be interested in this)

Literature Review for: "Implications of Driving Patterns on Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Plug-in Hybrid Electric Vehicles," *Leon Raykin, Heather L. MacLean, and Matthew J. Roorda,* TRB 2012 (disk)

- Stakeholder group + research area focus: Automotive + Travel Behavior
- Relevancy to the project: This study looks at "driving patterns" that include both driving distance and driving conditions.
- Data details: NHTS 2009

- Suggestions for additional data/information to further the study: None
- Details regarding use of data: all straightforward
- Insights into the stakeholder group:
  - Driving distance as a data item is important because it determines the fraction of travel in each operating mode (gas or electric) and therefore the fuel efficiency of the vehicle in use.
  - Second, driving conditions such as driving speed and fluctuations in speed associated with congestion affect the fuel efficiency of PHEVs.
  - For hybrid vehicles (including both PHEVs and HEVs) low speeds and high congestion tend to result in higher fuel efficiency than high speeds and low congestion, while the opposite is true for ICEVs (Internal combustion engine vehicles).
  - Accordingly, fuel efficiency of PHEVs is higher during city than during highway driving conditions
- Possible issues to consider for this stakeholder group:
  - Need for 'naturalistic driving behavior' studies
  - Market implication is PHEVs are more fuel efficient for low-speed congested driving (commuters)

### 8.2 Interview Guide

***Introductory Statement***

Our research team is investigating the types of data used to better understand (1) travel behavior and household vehicle ownership and usage patterns, (2) the siting of electric vehicle recharge stations, and (3) the design of electric vehicles. This is a preliminary research effort, designed to identify whether there are common data needs and interests across the automotive, utility, and travel behavior/transportation industries. If common data needs and interests are identified, a larger study will be considered to more fully investigate whether data sharing opportunities among the three stakeholder groups might exist. The research is funded by the National Cooperative Highway Research Program.

**This interview** will focus on efforts underway in the ____ industry and particularly the data to support those efforts. We anticipate this to take about 45 minutes. Do you have any questions before we begin?

***General Questions, Asked of All Stakeholders***

- To start, thinking specifically about preparing for a growing electric vehicle market, how important of an issue is this for your industry?
  - What are your industry's main areas of research with regards to the electric vehicle market?
  - What type of timeline or horizon are you planning for?
  - How would you describe the EV market?
- What are the main data needs or priorities in researching this issue?
  - What is the main source of data for these studies?
  - Is the focus residential or commercial? Why?
  - What type of data do you see directly collected by members of your industry?

- Are you familiar with industry studies that predict (1) household vehicle ownership and usage patterns, (2) the siting of electric vehicle recharge stations, or (3) the design of electric vehicles?
    - Are they largely qualitative or quantitative?
    - For the quantitative models, what type of data is used? What are the analysis outputs?
    - Aside from yourself, could you name another three to five top industry experts in the field for each of the questions?
- In transportation planning, agencies regularly conduct travel behavior studies, designed to create a snapshot of travel patterns within a specific region, at the statewide level, and at the national level. These surveys document demographic characteristics about the household, the household members, and their vehicles. They also document travel for a set period of time, typically 24-hours. With regard to the travel, the key variables are trip purpose, travel mode, trip start and end times, and origins and destinations of travel. Most agencies also now add a GPS component to their surveys, collecting detailed personal and vehicle movement data for a time period ranging from a day to a week or longer.
    - How useful would this data be within the context of the ____ industry planning efforts?
    - What type of travel behavior data have you seen used in your industry?
        - Probe for use of NHTS, origin-destination data from vendors such as AirSage or INRIX that compile in-vehicle or cell phone movement data, regional or state household travel surveys
    - Would data for 24-hours be sufficient or would data be needed for a longer time period? If longer, how long?
    - Are there specific details about travel behavior important to your industry studies that you need but have not been able to locate?
        - For example, travel surveys document local trips as well as long distance trips. Is knowing the frequency of trips over (or under) a certain distance threshold useful?
        - And would attitudes regarding distance capability for an electrified vehicle and willingness to use a second household vehicle or rent a car for trips longer than X distance be important for your studies?
    - Most studies are regional. How important is it to have information for a specific service area? How does the industry view the transferability of research between regions with regards to this topic?
    - How useful is demographic data to these studies? How important is it/useful would it be to tie socio/demographic attributes to consumer information that is already being collected (like Coulomb data)?
- Aside from surveys, can you name other sources or secondary data that can be useful for the purpose and either exist or can be collected
    - Large public surveys often contain some attitudinal questions—such as attitudes on congestion, transit options, etc. Is the stakeholder interested in obtaining attitudes and existing level of knowledge of a broad population pertaining to environmental considerations and/or the impact of those considerations when choosing a vehicle?

- Do you or others in your industry take advantage of data sharing programs like the Hydrogen Secure project or the Transportation Secure Data Center at NREL?
- Should this research show that there are common data needs across the three stakeholder groups of interest, would there be interest among industry stakeholders to consider partnering to collect data?
    - Based on how the industry operates, what is the best way to approach such a partnership?
    - Would there be concerns about data confidentiality or privacy?
    - What institutional barriers would need to be considered?
    - What does the public sector have to offer that would be of value to the stakeholder's industry? For example, response rates might be better for a public agency sponsored survey, public agencies might have larger population samples and more interest in a statistically representative survey, other?
    - How can state and regional agencies develop partnerships with industry so that both partners are satisfied? Are there other agencies besides local and State transportation planners (California Air Resources Board, AAA, EPA?) that would be interested and should be included?
    - In addition to primary data collection activities, are there potentials for public-private partnerships to increase public knowledge and awareness of the impact of internal combustion engines on the environment? For instance, the utility companies have well-developed educational campaigns designed to encourage people to conserve energy at home (Demand-side management). Is developing public-private partnership to educate and encourage car owners/drivers to conserve gasoline and reduce GHG emissions a viable option?

### 8.2.1 Automotive Stakeholder Questions

The main focus of this discussion is to understand the state of the practice in evaluating the nascent Electric Vehicle market. We are specifically seeking to better understand the type of data that are typically collected by researchers in the automobile industry and how these data may be used in conjunction with publicly collected and available data. Further, we are also seeking to better understand the type of data that researchers may be interested in, but do not currently collect due to reasons such as high costs, compressed schedules and other concerns.

***How Do Preferences Influence Vehicle Design?***

- To what extent do you consider attitudinal factors such as driver aggressiveness, driving behavior, design aspects such as vehicle accessories and other extraneous factors such as fuel price, terrain, and climate during the vehicle design stage?
    - Which are most important within your industry's research and why?
    - How do these factors influence decisions regarding EV range or fuel economy for PHEVs?
- In looking at some of the literature and conference presentations, it seems that factors such as the number of household vehicles and usage of those vehicles, income, attitudes and preferences, along with travel distance play some role in determining the type of hybrid/electric vehicle that is best suited for consumers based on prevailing vehicle fleet trends. In the scheme of things, how important are these factors?

- When considering factors that affect or improve PHEV performance, how important are things such as consumer education, GPS based-predictive technologies, or intelligent applications for route guidance and cruise control? And do these factors come into play more within the context of boosting sales, improving reliability of PHEVs, or some other design aspect?

***Battery***

Batteries are a key component in electric vehicle design and ultimately determine the range of the electric vehicle and purchase costs. We are interested in better understanding the type of data that automobile companies look at to make decisions, and identifying how travel behavior data can be used to perform analyses related to batteries, such as assessing the cost vs. benefit of different size batteries, and to what extent partnering with public enterprise to economize data collection costs might make sense.

- To what extent do factors such as trip lengths and duration, vehicle ownership and usage of those household vehicles affect decisions regarding the composition, size and type of battery needed such as lithium vs. nickel metal hydride, 5 kWh vs. 10 kWh.
- Do factors such as regional utility pricing effects, market conditions, and level of use/size of battery affect the pricing of batteries? If so, what data influences the decision?
- Has there been an analysis of whether consumers would like to own or lease a battery? What kind of data do automobile companies look at? How does this influence design?

***Charging***

Based on our preliminary research, it seems like charging behavior of consumers and type of chargers are important in developing a blue print for designing utility infrastructure necessary to support EVs.

- What are the key factors that influence the rate at which batteries are discharged – weather, trip duration (idling), terrain, vehicle accessories? Are there some factors that are more important than others? Factors that could influence discharging include the mode in which the vehicle may operate – charge sustaining, charge depletion.
- Does the time taken to charge a battery depend on the type of battery? Does the rate of depletion of charge depend on the type of battery? We ask because it seems like the stop times and number of stops observed in travel behavior data, and the location of the vehicle at home, work, etc. would be correlated with where/when/how do people charge batteries.

### 8.2.2 Utility Stakeholder Questions

- Is there a general plan to modify the utility infrastructure to meet/better meet the needs of PHEV/EV customers? If so, in what ways and what is being done?
    - What is the general thought with regards to the current and near future impacts of EVs on the grid?
    - Has there been any benchmarking of model outputs with regards to forecasting additional grid demand?
    - If yes to the main question: how would these changes affect those who do not own PHEV/EVs?

- How important is data regarding the current behavior of EV owners? Are you aware of any studies or data documenting where and when they charge their cars, whether they had to install a plug in their garage, and if so, the cost and whether that cost was subsidized? **Note – prior to asking this question, we should review the data being collected at the Idaho National Labs*
- What travel behavior related data elements do you think would be beneficial to electric power operators in predicting demand?

### 8.2.3 Closing, asked of all stakeholders

- Is there anything else on this topic that you'd like to mention?

We appreciate your time. We're currently holding similar interviews with others in the travel behavior, utility and automotive industries. Our plan is to hold a web-based meeting later in the summer, bringing together stakeholders from all three areas, to explore possible areas of synergy between the industries. Would you be available and interested in participating?

## 8.3 Interview Notes

Interview Notes are included here in alphabetical order. A total of four interviews were conducted:

1. Jeff Gonder, Eric Wood, and Tony Markel, National Renewable Energy Labs
2. Edward Kjaer, Southern California Edison
3. John Krumm, Microsoft,
4. Kate Tomford, Illinois Energy

### 8.3.1 Task 108 Interview Summary #1

*Jeff Gonder, Eric Wood, and Tony Markel – National Renewable Energy Labs*

***May 23, 2012, from 5 – 6 pm CDT/ 4- 5 MDT***

In attendance: Jeff Gonder, Eric Wood, and Tony Markel, NREL
Stacey Bricka, TTI
Sashank Musti and Anurag Komanduri, Cambridge Systematics
Nancy McGuckin, Travel Behavior Associates

Industry: Research/Vehicle Design/Utility

Stacey started the discussion with a general overview of the project to provide context to our project and this interview. This was followed by the NREL staff providing background on related activities. The interview details are presented below, following the interview guide outline. The interview itself followed a natural flow of conversation.

***Part 1: General questions, asked of all stakeholders***

- To start, thinking specifically about preparing for a growing electric vehicle market, how important of an issue is this for your industry?
    - What are your industry's main areas of research with regards to the electric vehicle market?

        - *Research area of Tony Markel: Leads a team that studies the grid integration of electric vehicles, impact of vehicles on grid, power transfers between grid and electric vehicle when the vehicle is not in use, renewable resources bi-directional transfers and various infrastructure pricing scenarios.*
        - *Eric Wood: Studies consumer cost calculations and battery life modeling. Analyzes longitudinal travel data including multi-day, multi-month data sets. Studies various vehicle use scenarios. Most valuable data set that Eric uses is the Puget Sound Regional Council (PSRC) data because it captures multi-day driver behavior.*
        - *Jeff Gonder: Commute Atlanta data set also provides similar level of detail but due to privacy concerns is not as accessible as the PSRC data set.*
    - What type of timeline or horizon are you planning for?
        - *EV Market will take some time for significant market penetration. 20 year horizon in mind. EV market share dependent on purchase costs, battery costs, fuel prices and low payback period. High adoption rates would be possible under situations with closer cost parity.*
    - How would you describe the EV market?
        - *Value differentiation is required for market penetration. Comparisons to hybrid cars are not substantiated because payback period of a hybrid car is faster. Also, distinctive body style of these vehicles helps market penetration among early adopters/buyers wanting to make a "green" statement. For example, Chevy Volt and Nissan Leaf also have distinctive body styles.*
- Are you familiar with industry studies that predict (1) household vehicle ownership and usage patterns, (2) the siting of electric vehicle recharge stations, or (3) the design of electric vehicles?
    - *Ideal data set should consider opinions from consumers and capture their needs and expectations. It should also capture real world fuel consumption of drivers. GPS onboard surveys would be helpful in capturing real world driver behavior and parking location. Road grade information will also be helpful. Data about air conditioning use, climate control systems and cabin temperature (ambient environmental conditions) affect range capabilities of electric vehicles. Data that would help analyze driver's cell phone use while driving could help quantify autonomous driving functions.*
    - Aside from yourself, could you name another three to five top industry experts in the field for each of the questions?
        - *Peter Savagian, Michael Harpster and Kristen Zimmerman from GM would be good industry experts to talk to. Jeff Gonder mentioned that he knew someone at Chrysler who would be interested in the topic.*
- In transportation planning, agencies regularly conduct travel behavior studies, designed to create a snapshot of travel patterns within a specific region, at the statewide level, and at the national level. These surveys document demographic characteristics about the household, the household members, and their vehicles. They also document travel for a set period of time, typically 24-hours. With regard to the travel, the key variables are trip purpose, travel

mode, trip start and end times, and origins and destinations of travel. Most agencies also now add a GPS component to their surveys, collecting detailed personal and vehicle movement data for a time period ranging from a day to a week or longer.

- What type of travel behavior data have you seen used in your industry?
  - Probe for use of NHTS, origin-destination data from vendors such as AirSage or INRIX that compile in-vehicle or cell phone movement data, regional or state household travel surveys
  - *Analysis and research that NREL does usually uses data from typical travel surveys with GPS add-ons (PSRC and NHTS data). AirSage and INRIX data not used in analysis.*
  - *Most of the studies address residential concerns because most data sets capture household behavior.*
  - *NREL is collecting travel behavior data for medium and heavy duty vehicles (commercial vehicles).*
- Would data for 24-hours be sufficient or would data be needed for a longer time period? If longer, how long?
  - *Time period of ideal data set would be around a year because it will help capture seasonal variability. Attitudinal questions could help expand on analysis. Actual and reported behavior differences could also help analyze behavior. Second by second data along with demographics could help capture driver behavior and aggression. GPS data helps analyze trip under-reporting.*
- Most studies are regional. How important is it to have information for a specific service area? How does the industry view the transferability of research between regions with regards to this topic?
  - *Transferability of analysis and conclusions across regions is not yet underway. Representativeness is not enough to draw conclusions across regions.*

- Should this research show that there are common data needs across the three stakeholder groups of interest, would there be interest among industry stakeholders to consider partnering to collect data?
  - Based on how the industry operates, what is the best way to approach such a partnership?
    - *Common data needs exist across different stakeholder groups. For example, automobile manufacturers, utility companies and research organizations (NREL, ANL) have some data needs in common. Best way to approach different industries is to focus on individual needs and provide them with solutions to increase efficiency and reduce costs of administering the surveys. Capturing information from specific demographic market segments would be helpful to certain auto manufacturers instead of a random sample.*
  - Would there be concerns about data confidentiality or privacy?
    - *Regulatory issues exist in automobile manufacturers. Privacy of individual participants is also something to worry about.*
  - In addition to primary data collection activities, are there potentials for public-private partnerships to increase public knowledge and awareness of the impact of

internal combustion engines on the environment? For instance, the utility companies have well-developed educational campaigns designed to encourage people to conserve energy at home (Demand-side management). Is developing public-private partnership to educate and encourage car owners/drivers to conserve gasoline and reduce GHG emissions a viable option?

- *Best way to partner with different industries would be to collaborate on research and pool funds. Working with SAE to develop standards would be another way to work with different groups.*

***Part 2: Utility Stakeholder Questions***

- Is there a general plan to modify the utility infrastructure to meet/better meet the needs of PHEV/EV customers? If so, in what ways and what is being done?
  - What is the general thought with regards to the current and near future impacts of EVs on the grid?
    - *Impact on grid depends on a number of factors including age of transformers/infrastructure, assumptions made while building the transformers, size of residential market (number of houses) and location of electric vehicles. Most of the effects on the grid would be localized.*
- How important is data regarding the current behavior of EV owners? Are you aware of any studies or data documenting where and when they charge their cars, whether they had to install a plug in their garage, and if so, the cost and whether that cost was subsidized?
  - *UC Davis (Tom Turrentine) has data about current travel behavior of early adopters.*
- What travel behavior related data elements do you think would be beneficial to electric power operators in predicting demand?
  - *Characteristics of data elements that would be useful to utilities include longitudinal snapshots of behavior, geographic distribution, trip lengths, time of day, number of electric miles, charging location, time of charging, parking location and charging preferences of consumers.*

***Part 3: Closing, asked of all stakeholders***

- Is there anything else on this topic that you'd like to mention?
  - *One of the utilities in the NW part of Chicago has done some analysis on smart charging, but not specific to EVs.*

### 8.3.2 Task 108 Interview Summary #2

*Ed Kjaer, Southern California Edison*

*Friday, June 1, 2012 from 5 to 6 pm CDT/3 to 4 PDT*

In attendance: Ed Kjaer, SCE
Stacey Bricka and Chris Simek, TTI

Industry: Utility (consumer market perspective)

Stacey started the interview with a general overview of the project top provide context to our project and this interview. This was followed by Ed Kjaer providing insights into the EV

market, from the utility industry perspective. Given that the Southern California (Los Angeles) region has almost 5,000 electric vehicles (EVs) operating on the roadway network on a daily basis, this interview speaks to issues that will be facing other utilities as they transition from R&D to an EV actual market. This forward-looking industry perspective was not identified as part of the literature review, thus this interview focused on obtaining insights into the future of the EV market rather than the general questions of the interview guide. Details of this interview follow, not necessarily presented in the order in which they were discussed.

Ed Kjaer has more than 20 years of experience in the EV market, both in the automotive as well as the utility industries. The primary aim at Southern California Edison (SCE) has been to research emerging EV technology, investigating how the grid will talk to cars AND how grid will react to this new industry. SCE is the only utility with an electric vehicle technology center, allowing them to research the emerging electro-drive technology and resulting implications for the grid.

SCE has almost 5,000 customers in their service area operating EVs. They see this as a competitive market and sales are expected to grow overtime as people recognize the benefits and see vehicles as a viable alternative. As this market grows, the EV owners are expected to look to their utility companies in a more interactive manner than in the past.

As a whole, the utility industry has done a good job of providing reliable electric services without getting into the fundamental mechanism required to deliver electricity. In other words, the utility has seen the customer as needing something (electricity) that they are willing to pay for and not ask any questions. The relationship has been about reliability and the customer did not care or want to know about the complexities involved with the delivery of electricity. Electric vehicle technology will change this.

SCE is leading the effort nationally in identifying how to best educate the EV market. They have invested in sophisticated efforts (lots of social media) to identify the best places to connect with EV owners and perspective owners. Prior to the EV market, car buyers did not consider consulting with the utility companies for information regarding how to fuel their vehicle. With EVs, the utilities are the best source of information regarding the technology, recharging options, and what type of driving patterns are best supported by an EV.

To that end, SCE is also focusing on operationalizing the home to act as a plug in source, which is another aspect to their national outreach and education efforts. Right now, there is very low consumer awareness on the topic, related to the consumer's traditional interactions with the utility industry. As regions build their EV market, they must work alongside utilities to remove barriers that might inhibit the level of electric vehicle market penetration. This includes the utilities adjusting to a brand new use of the energy grid, which is very compelling in and of itself. This focus is both residential as well a commercial – recharging stations for the home, the workplace, fast charge stations at grocery stores and interim stop locations, etc.

SCE sees a situation where the common goal of serving this growing EV market draws together the automotive and utility industries. Areas of focus include universal plug-in technology, federal and state regulations, identifying the right details to provide drivers real-time to effect driving range, etc. For example, key to effective use of the grid is efficient driving habits. EVs designed with technology to provide real time feedback can contribute greatly to this goal by

providing customers with situational awareness. Real time feedback is the key to helping customers better use the EV technology. Screens give real-time feedback to the drivers, helping them to drive more efficiently and also helping them become more familiar with the technology, thereby reducing range anxiety. EV drivers then use the grid more efficient, and smart grids are equipped to manage the recharging load. EVs equipped with this technology allow consumers to manage their consumption of energy in real time. Gone will be the days of receiving a startling electric bill at the end of the month, because drivers will know (at any given moment) how much electricity they've consumed. For the first time, the customer will be part of the system, not just a consumer.

With regards to data needs, SCE and the automotive industry are using real-time data from the EVs being driven in the southern California region. Although they recognize that this reflects the experiences of early adopters or fast adopters, their charging activities are important in informing industry activities. For example, faster charging is not better, which is contrary to popular thinking. Lots of customers don't mind charging at 110V (overnight . . .when they are sleeping . . . . this is more than adequate amount of time). Today utilities need to focus on the consumer experience of early adopters/fast adopters, because they will become the best sales folks for the EV market. We can expect the "early adopter" stage of this market to last for another five years – and while the data has noise, it works for the purposes of informing outreach and education, as well as perspective customers.

When asked about "ideal" or missing data, it appears that travel survey data (particularly GPS streams) would help the utilities to better understand how vehicles are being used (all vehicles), then understanding certain driving patterns better to extrapolate those VMT patterns to electric-only vehicles and related grid demand.

Currently, the consumer link is the weakest link in the EV market. All of the effort and focus has been put on making a good car . . .a really, really good car. Now, we (all industries) need to find out how to make people buy them. Ed likens it to Apple products. People buy Apple products, because they are cool. They have unique operating systems and people wait in line to buy them because they have to have it. It's pure and simple. Electric cars will have the same characteristics. Customers that are coming into the market are looking to stand on shoulders of those that came before them. Corporate speak does not work at all. YouTube video testimonials by the early adopters are very popular for this market.

With regards to the vehicle design (with the real-time feedback), this is well received by the EV owners. Customers like instant feedback - they want to share data, but they expect to see something in return. The automotive industry does not yet see the value of the customer as marketers of their product. Even so, EV owners regularly volunteer for their driving statistics to be widely shared – and even compete for "best" scores, mpg, and other stats (see www.voltstats.net for example). With recent technological advances, society is moving into "gaming mode" and this is reflected in the behavior of the early adopters. Understanding the parameters and competing for the best driving ranges, using real-time feedback to maximize battery life, these are all behaviors not really understood by the industry but critical in understanding this growing EV market.

In terms of other contacts, Ed provided the following names:

- Chelsea Sexton, founding member of Plug-in America
- Mark Duval, EPRI
- Mark Perry, Nissan.

Mr. Kjaer, Ms. Sexton, Mr. Duval, and Mr. Perry are all expected to attend the 2012 Plug-In conference in San Antonio. It may be possible to convene a meeting on this topic at some point during the San Antonio event.

### 8.3.3 Task 108 Interview Summary #3

*John Krumm – Microsoft (interviewee comment on these notes is pending)*

*May 18, 2012, from 11 am to Noon CDT/9 am to 10 am PDT*

In attendance: John Krumm, Microsoft
Stacey Bricka and Chris Simek, Texas Transportation Institute

Industry: Mobile Computing

Stacey initially provided a general overview of NCHRP, NHTS, regional transportation surveys to provide context to our project and this interview. This was followed by John providing background on related Microsoft projects. The interview details are presented below, following the interview guide outline. The interview itself followed a natural flow of conversation.

***Part 1: General questions, asked of all stakeholders***

- To start, thinking specifically about preparing for a growing electric vehicle market, how important of an issue is this for your industry?
    - What are your industry's main areas of research with regards to the electric vehicle market?
        - *6-7 years ago, we started collecting GPS data. We initially used vehicle based loggers then moved to person based. The analyses of these data included:*
            - *General travel behavior (trip times, destinations, routes, etc.)*
            - *Prediction. For instance . . . If we have a partial trip route, can we predict the destination and route? If so, we can provide some helpful information on downstream road conditions (accidents, closures, etc.), or, in the case of PHEVs, charging stations. Can we use it for marketing?*
            - *Can we predict when person will be home or not, using time stamped GPS data? If so, we could identify when homes should be heated or not (energy conservation).*
            - *Can we recommend where people should go, given what we know about their travel profile?*
                - *Example . . . you're almost out of gas . . . can we tell you where to go for gas, given your current location?*
                    - *This specific type of analysis is leading into work that will help reduce range anxiety for PHEV owners/potential owners.*

        - *Can we make road maps using only raw GPS data (with no underlying transportation network (just raw GPS traces)?*
    - What are the main data needs or priorities in researching this issue?
        - *It is all about giving travelers good suggestions on where to go, given where they are and where we think they are going. In order to make these suggestions, we need to understand their personal travel habits. The better we understand these habits, the better our suggestions are. This is the foundation of place-based advertising.*
        - *The 24-hour snapshot of personal travel behavior provided by NHTS data is useful. For example, we use the NHTS to obtain probability distributions of trip time. We then use this to better inform/calibrate our models (we may not know the exact location someone is going, but we know the probability if it being an x-minute auto trip away from the origin). However, the long term travel patterns provided with the GPS data is better for estimating personal "habitual" travel. It is from these habitual travel patterns that we can base our prediction.*
    - What is the main source of data for these studies?
        - *GPS data*
            - *In vehicle (passenger vehicle) GPS sample size was 317 vehicles, with data for each vehicle ranging from 2-weeks to more than a year*
            - *Person based GPS sample size was 54 person*
            - *In vehicle (commercial vehicle) GPS sample size was 350 vehicles*
                - *We are most interested in personal travel . . . fleet vehicle information is not as important*
        - *To this point, we have not collaborated much with the utility or vehicle industry. We just started working with Ford.*
    - Is the focus residential or commercial? Why?
        - *We like to study regular people. It makes our work more interesting, and it is more applicable to the Microsoft business model (selling mobile computing products to people). So, we focus on residential.*
- Are you familiar with industry studies that predict (1) household vehicle ownership and usage patterns, (2) the siting of electric vehicle recharge stations, or (3) the design of electric vehicles?
    - Aside from yourself, could you name another three to five top industry experts in the field for each of the questions?
        - *Lili Cao is a former summer intern of mine who now works for Apple. We collaborated on a mobile computing paper together.*
        - *Dimitar Filev works for Ford. We are collaborating on some route prediction work.*
- In transportation planning, agencies regularly conduct travel behavior studies, designed to create a snapshot of travel patterns within a specific region, at the statewide level, and at the national level. These surveys document demographic characteristics about the household, the household members, and their vehicles. They also document travel for a set period of time, typically 24-hours. With regard to the travel, the key variables are trip purpose, travel mode, trip start and end times, and origins and destinations of travel. Most agencies also

now add a GPS component to their surveys, collecting detailed personal and vehicle movement data for a time period ranging from a day to a week or longer.

- How useful would this data be within the context of the ____ industry planning efforts?
  - *It would be very useful, because it involves a mobile aspect that cannot be obtained from someone sitting at their desk surfing the net with their PC.*
  - *People are surprisingly willing to give up location data in return for something, whether it is a map, a summary document . . . whatever.*
- What type of travel behavior data have you seen used in your industry?
  - Probe for use of NHTS, origin-destination data from vendors such as AirSage or INRIX that compile in-vehicle or cell phone movement data, regional or state household travel surveys
    - *We have looked at the NHTS for OD information and tried to obtain (unsuccessfully) the add-on data in CA and VA, because it has more detail (the specificity of the standard NHTS is not sufficient for their purposes).*
    - *Note: As a private corporation, they have had difficulties getting permission to access the geocoded add-on data.*
    - *We have looked at ATR data for model validation*
    - *Had not looked at INRIX or Airsage*
  - *We have looked at the Reality Mining Dataset at MIT. It sounded very similar to Airsage data.*
  - *We are aware of the NREL secure data center via Ed Tate (but it was not evident if they had actually used it).*
- Would data for 24-hours be sufficient or would data be needed for a longer time period? If longer, how long?
  - *Longer is better, because it allows us to identify travel "habits," which helps us predict behavior.*
- Are there specific details about travel behavior important to your industry studies that you need but have not been able to locate?
  - For example, travel surveys document local trips as well as long distance trips. Is knowing the frequency of trips over (or under) a certain distance threshold useful?
    - *It would be great to know the geocodes for every specific location that is visited on a trip. A lot could be predicted with this information using algorithms. Furthermore, it could be validated with non- location based travel behavior data (attitudinal and/or socio-demographic).*
  - And would attitudes regarding distance capability for an electrified vehicle and willingness to use a second household vehicle or rent a car for trips longer than X distance be important for your studies?
    - *Attitudinal data is not terribly important to us at this time.*
- How useful is demographic data to these studies?
  - *Demographic data is somewhat important, but it's not as important as actual travel information. Demographics help us predict what we don't already know.*

- Aside from surveys, can you name other sources or secondary data that can be useful for the purpose and either exist or can be collected
    - Large public surveys often contain some attitudinal questions—such as attitudes on congestion, transit options, etc. Is the stakeholder interested in obtaining attitudes and existing level of knowledge of a broad population pertaining to environmental considerations and/or the impact of those considerations when choosing a vehicle?
        - *It would be great to have data for each trip end regarding time flexibility. For instance, do you have to be at a specific location at a specific time or do you have some wiggle room?*
        - *It would be great to have data for the traffic/weather conditions at the time of the trip.*
- Do you or others in your industry take advantage of data sharing programs like the Hydrogen Secure project and the Secure Data Center at NREL?
    - *We are aware of it and have made contact with these folks.*
- Should this research show that there are common data needs across the three stakeholder groups of interest, would there be interest among industry stakeholders to consider partnering to collect data?
    - Based on how the industry operates, what is the best way to approach such a partnership?
        - *Microsoft would be very open to collaboration.*
        - *Mobile computing folks are desperate for data to be mined to help further our cause.*
        - *The best way to approach the mobile computing community would be to identify 1-2 folks at each mobile computing company who know how valuable the data are. Then, use them as champions to convince their management. This is a better approach than going directly to management.*
    - Would there be concerns about data confidentiality or privacy?
        - *This is not a big deal.*
    - What institutional barriers would need to be considered?
        - *I really cannot think of any. If we are all working together in a cooperative we can do a better job all around. It's good for everyone.*
        - *Getting the GPS data is very difficult, so we'd be happy to be able to obtain it in any way we can . . . collaboration would be welcome.*
    - What does the public sector have to offer that would be of value to the stakeholder's industry? For example, response rates might be better for a public agency sponsored survey, public agencies might have larger population samples and more interest in a statistically representative survey, other?
        - *The random nature of HHTS sampling is a huge selling point. It produces a better final product. Furthermore, the NHTS data is easily available and the documentation is good. These are also huge selling points.*

***Part 2: Closing, asked of all stakeholders***

- Is there anything else on this topic that you'd like to mention?

- *In my opinion, the ideal study would collect finely sampled GPS data that shows where people went (OD) and how they got there (mode and route).*
- *It is also important to know that a dataset with a larger sample size is more beneficial than a dataset that covers a larger geography.*
- *John would be interested in attending the panel meeting/conference.*

Notes

1. It was interesting that a lot of the data that was identified as useful is already being collected, but access to private sector companies is not as forthcoming as it is for Universities and public agencies.

### 8.3.4 Task 108 Interview Summary #4

*Kate Tomford – Energy Office, Illinois Department of Commerce and Economic Opportunity*

*May 22, 2012, from 9:30 – 10:30 am CDT*

In attendance: Kate Tomford, Illinois Department of Commerce and Economic Opportunity
Stacey Bricka and Chris Simek, Texas Transportation Institute
Sashank Musti, Cambridge Systematics

Industry: State Agency/Utility

Stacey started the discussion with a general overview of the project and regional transportation surveys to provide context to our project and this interview. This was followed by Kate providing background on related Illinois Energy activities.

Kate works for the Illinois Department of Commerce and Economic Opportunity, and is engaged in energy efficiency programs, in addition to EV programs and other energy and environmental initiatives. Recent state legislation has been passed that formed the Electric Vehicle Advisory Council. Kate chairs this council, and is spearheading an effort to allocate additional funding that was obtained in prior legislation (2009) for PHEV incentive programs / policy analysis. The 2009 legislation (a capital funding initiative) is not specific on how a $10M appropriation to EVs should be spent; the only description is that it should be spent on "transportation electrification infrastructure projects; including, but not limited to grants and loans for the purpose of encouraging electric car manufacturing and infrastructure for electric vehicles."

Currently, there are three big programs in IL regarding EVs.

- Grant program for manufacturing projects for EVs or charging station equipment (or their components), funded through the capital funding initiative passed in 2009.
- Rebates for charging stations that can be installed at residential, commercial, or public locations.
- The IL Alternative Fuels Rebate Program is for any sort of alt fuel vehicles . . . natural gas, E85, electricity. It pays for up to $4k in the cost of the vehicle itself (80% of the incremental cost of a conventional equivalent . . . .OR 10% of the MSRP (if no conventional equivalent). This program is through IL EPA.

North Carolina also has electric vehicle task force that is similar. It acts as a non-profit to help run public benefit fund. It is called Advanced Energy, and they have an Electric Vehicle Task Force. They have put together a lot of documentation that is specific to EV promotion, and were the recipient of a significant Federal grant for EV planning and deployment.

The interview details are presented below, following the interview guide outline. The interview itself followed a natural flow of conversation.

***Part 1: General Questions, asked of all stakeholders***

- To start, thinking specifically about preparing for a growing electric vehicle market, how important of an issue is this for your industry?
  - *It is a very high priority. The governor is very interested. I have regular meetings to brief him on state of the state of EVs in IL. IL is adding EVs to their fleet (+15 vehicles this year).*
  - What are your industry's main areas of research with regards to the electric vehicle market?
    - *We focus more on infrastructure (charging stations). Work closely with other agencies on legislation that will exempt charge stations from being regulated as public utilities. We are also working on legislation to ensure that stations are installed properly. We do lots of education and outreach.*
    - What type of timeline or horizon are you planning for?
      - *Good question. Lots of internal debate on this topic. Our goal set out by the EV Advisory Council was to have 100k EV on IL road by 2015, but it does not look like it will be reached.*
    - How would you describe the EV market?
      - *It is reflective of what you have heard in the media, with sales slower than anticipated. There has been lots of investment by auto manufacturers. This trend will continue to build as OEMs continue to promote/invest in their EV lines. In IL we think there are fewer than 500 EVs on the road (estimate via EV registration and IEPA rebate applications). The IL Secretary of State's EV registration class does not include plug-in hybrid EVs (only pure EVs captured), so relying on their data gives us a low estimate.*
- What are the main data needs or priorities in researching this issue?
    - What is the main source of data for these studies?
      - *EV registrations, hybrid sales data, rebate program applications.*
      - *The state gave a grant to the City of Chicago to establish a Chicago-region EV charging station network. The vendor that the City selected relied on various data sources to determine to plan their target locations. There is also a gentleman at Northwestern University (Diego Klabjan) who has created a tool to optimize charging station locations based on public information sources.*
      - *We have not done any survey research or funded any research to collect information to use regarding EVs and their impact on the utilities.*
    - Is the focus residential or commercial? Why?
      - *We know from published studies that most EV charging will be residential, but the focus of our government funding has been on stations at public and*

*commercial/retail locations. We would also like to see more charging stations installed in multi-family residences, but the policies around the use of chargers in common parking areas can be challenging.*

- What type of data do you see directly collected by members of your industry?
  - *There has been survey research data collection to identify market penetration, acceptance of smart charging, and collaborations between utilities and OEMs to identify multiple data points from individuals driving EVs (NC/Chevy/OnStar collaboration as an example).*

- Are you familiar with industry studies that predict (1) household vehicle ownership and usage patterns, (2) the siting of electric vehicle recharge stations, or (3) the design of electric vehicles?
  - Are they largely qualitative or quantitative?
    - *Quantitative*
  - Aside from yourself, could you name another three to five top industry experts in the field for each of the questions?
    - *Diego Klabjan at Northwestern*
    - *Kristen Zimmerman or Britta Gross at GM*
    - *Ted Bohn at Argonne National Lab*
- In transportation planning, agencies regularly conduct travel behavior studies, designed to create a snapshot of travel patterns within a specific region, at the statewide level, and at the national level. These surveys document demographic characteristics about the household, the household members, and their vehicles. They also document travel for a set period of time, typically 24-hours. With regard to the travel, the key variables are trip purpose, travel mode, trip start and end times, and origins and destinations of travel. Most agencies also now add a GPS component to their surveys, collecting detailed personal and vehicle movement data for a time period ranging from a day to a week or longer.
  - How useful would this data be within the context of the ____ industry planning efforts?
    - *Very useful for many applications:*
      - *Location optimization. Help guide installation of statewide network of charging stations.*
      - *What type of dwelling are people living in, and does it offer parking that can be equipped with charging equipment?*
      - *What is the average commute distance? This could be used to determine if the current battery range are sufficient w/o having to charge?*
      - *Promotion of EVs in general will be contingent on utilities' knowledge of people's EV charging habits so that they can adequately address any reliability issues with the electricity distribution system.*
  - Would data for 24-hours be sufficient or would data be needed for a longer time period? If longer, how long?
    - *24-hr is sufficient to get a glimpse of commuting patterns, but I think EV range anxiety is generally related to non-commuting trips, which would require a longer time frame to identify.*

    - How useful is demographic data to these studies? How important is it/useful would it be to tie socio/demographic attributes to consumer information that is already being collected (like Coulomb data)?
        - *It would be useful to see how demographics like income affect EV adoption.*
        - *Demographics would be good to ensure that the charging stations are located equitably across a geographic area (environmental justice).*
- Aside from surveys, can you name other sources or secondary data that can be useful for the purpose and either exist or can be collected
    - Large public surveys often contain some attitudinal questions—such as attitudes on congestion, transit options, etc. Is the stakeholder interested in obtaining attitudes and existing level of knowledge of a broad population pertaining to environmental considerations and/or the impact of those considerations when choosing a vehicle?
        - *It would be extremely useful to get an accurate estimate of how many EVs are actually on the road. OEMs don't want to share details*.
- Do you or others in your industry take advantage of data sharing programs like the Hydrogen Secure project or the Transportation Secure Data Center at NREL?
    - *No.*
- Should this research show that there are common data needs across the three stakeholder groups of interest, would there be interest among industry stakeholders to consider partnering to collect data?
    - *Yes, potentially. Initially, it may be challenging to find the funds, but it would be of interest.*

***Part 2: Closing, asked of all stakeholders***

- Is there anything else on this topic that you'd like to mention?
    - *ComEd, the electric utility in the NW part of Chicago, has done a pilot on smart metering, but the study did not specifically address the application of smart grid to EVs.*

### 8.4 Stakeholder Workshop Discussion Guide

Improving Travel Behavior Data for Alternative Fuel Vehicles: A Scoping Study Workshop

Thursday, July 5, 2012 from 2 to 4 pm ET

Friday, July 6, 2012 from 3 to 5 pm ET

**Attendee List:**

Thursday:

- Jeff Gonder National Renewable Energy Lab (and panel member), Vladimir Livshits Maricopa Association of Governments (panel member and modeler), Elaine Murakami FHWA (and panel member),
- Greg Giaimo Ohio DOT (modeler),
- Bernard Neenan EPRI (utility industry), John Smart Idaho National Lab

Friday:

- Tonia Buell Washington State DOT (panel member),
- Eric Wood National Renewable Energy Lab, John Krumm Microsoft,
- Diego Klabjan Northwestern University, Reza Farzeneh (TTI), Jeff Barghout, Advanced Energy (NC), Charles Zhu and Nick Nigro from Center for Climate Energy Solutions, Nukal Sathaye Ecotality

Team Members (present for both workshops):

- Stacey Bricka, Chris Simek, Nick Woods, Tina Geiselbrecht, TTI,
- Anurag Komanduri, Sashank Musti, Cambridge Systematics

Research Objective: Confirm preliminary findings regarding research into shared data needs and interests between travel behavior and electric vehicle researchers. Discuss and identify a framework for better coordination of travel behavior data collection and accessibility across multiple stakeholder groups.

### 8.4.1 Introductions and Meeting Overview

*(Tina, 30 MINUTES)*

Welcome everyone to the meeting, review meeting objectives, and lead the group in introductions.

- IF NOT DONE SO ALREADY, START ADOBE CONNECT LINK (SEE ABOVE FOR LINK)
- Software review (Tina Geiselbrecht)
  - Go over Tina's list – mute/unmute, chat box, polls, raise hands, symbols.
  - Any preferences we have for attendees?
  - Reminder to turn cell phones off/mute.
  - Any other administrative items to cover?
- Meeting objectives:
  - To vet preliminary research regarding the intersection of data needs between travel behavior and electric vehicle research.
  - To discuss whether and how some type of data sharing partnership might work, possible barriers, and what we'd need to focus on to make this work. If attendees don't think it would work, why not?
  - To get input from the group on the priorities of the research needs identified.
- Divided group into 2 workshops to allow for better interaction in the web environment. Will take results from both workshops and combine them.

- Introductions – moderated.
  - Ask attendees to state Name, affiliation, and ***key areas of research in this topic***
  - Acknowledge the panel members on the call
    - Thursday: Jeff Gonder, Vladimir Livshits, and Elaine Murakami
    - Friday: Tonia Buell
  - Acknowledge the use of the webroom from FHWA/Elaine

- Introduce project team last.
- Here's what is coming. Mix of short presentations and discussion. End with prioritization exercise.

### 8.4.2 Project Scope and Preliminary Findings

*(Stacey Bricka) – 15 MINUTES (INCLUDING DISCUSSION)*

Refer to Handout #1.

In terms of background for today's discussion, there are three points I'd like to cover:

1. Information on the National Cooperative Research Program, our funding source
2. The transportation data we see as most relevant to this discussion
3. What our preliminary research is suggesting.

POLL

**NCHRP**. This project is funded through the National Cooperative Research Program, as a "proof of concept" study in that we are investigating whether this concept has sufficient interest and depth to warrant full NCHRP project funding.

- For those of you not familiar with NCHRP, it is a voluntary pooled fund research program supported by all state Departments of Transportation. Funds come from each state's apportionment of State Planning and Research funds.
- Research ideas can come from any source – the DOTs, federal agencies like FHWA, a lot are generated through those involved in the Transportation Research Board (TRB), which is a part of the National Academy of Sciences. A main focus of the various TRB committees is the generation of research ideas and problem statements for programs like NCHRP.
- There is an annual cycle, with problem statements submitted by September 15 of each year, then they are reviewed and voted on. A two-thirds vote is required to fund a full research project, which can range in value from $250k to $1 million. And, all problem statements considered must have support from the DOTs, their association (AASHTO), or FHWA.
- We'll come back to this at the end of the workshop.

This research idea came from a small group of travel behavior researchers, actually three independently wrote similar ideas that were combined. NCHRP saw value in the idea, but the question was whether we were at a point where there was sufficient interest across all stakeholder groups to warrant a full study. So they funded this smaller study to determine whether there is sufficient interest and evidence, and if so, to develop a research framework for the full study.

- Credit Jeff Gonder and Elaine Murakami for authoring the original idea

**Transportation Data**. We collect a lot of data to support transportation planning, both in terms of travel behavior as well as traffic data.

- On the TRAFFIC DATA side, transportation agencies collect data on volume and movement, across time. Not linked to any specific traveler, but does document congestion, speeds, and incidents that influence the patterns we see in the personal travel data at intersections or at particular points of interest on highways/roadways. Most of this data is collected passively, using GPS, cell phone traces, Bluetooth, etc. for the personal travel side and GPS data from truck fleets on the commercial side, which help to provide insights into level of service and system performance.
- On the TRAVELER side, most regional transportation agencies (Metropolitan Planning Organizations or MPOs) create snapshots of "typical travel" to document personal travel behavior through "Household Travel Surveys." Our methods are evolving, but generally, we have random samples of about 2000+ households where all members record travel for a 24-hour period. Most cases, at least 10% of these households have corresponding GPS data, sometimes for a longer period. The proportion and length of time GPS data is collected is evolving. (SCREEN SHOTS OF TRAVEL PATTERNS AND GPS DATA TRACES)

- The data is then fed into travel demand models, which are also evolving. Most models today focus on the individual trips made (to create that snapshot discussed earlier). However, we are moving to more complicated activity-based models that require more detailed data, for longer time periods. From the research that we've done on this project, our more advanced models will be requiring detailed data similar to what it seems like the EV researchers also need.
- Travel Survey Archives. There are two archives of travel survey data. The more traditional diary-based data is housed at the Travel Survey Archive at the University of Minnesota. Screen shot here, links to data and documentation.

  Second, newer archive with the GPS data is the Transportation Secure Data Center. Founded a few years ago by Jeff and Elaine to "save" data sets with the detailed spatial resolution collected by GPS and to provide access to the confidential data.

POLL

**Preliminary Results**. Prior to these workshops, the project team undertook a literature review and one-on-one interviews. Our goals were to answer 4 questions. As noted in your handout here's what we found …

- **Current data collection.** Small scale convenience samples from early adopters are being used, in conjunction with the National Household Travel Survey (NHTS) and regional travel surveys, to capture information about typical driving patterns and household vehicle fleet composition. Researchers have also used regional travel survey GPS data and small regional samples of naturalistic driving behavior studies to establish driving profiles.
- **Data gaps**. The most commonly cited data gap was the lack of longitudinal data, including consistently defined and collected data for tracking vehicle market penetration and changes in travel behaviors. Other areas where more data are required include (a) understanding recharging behavior, (b) evaluating range anxiety, and (c) recognizing early adopter behavior.

- **Major players**. The most significant players are the automotive industry, which is at the forefront of collecting information from early adopters; utility companies and state energy commissions and agencies; and other stakeholders, such as the national energy labs and mobile computing industries.
- **Differing perspectives.** Currently, interest in collaboration for data collection comes largely from the other stakeholders – the national labs, trade associations, and the mobile computing industry. Automotive companies are interested in the data potential but dependent on their own consumer behavior studies. Utility companies are keeping a watchful eye on the EV trend – even though the market is moving slower than original projected.

Turn back to Tina for discussion.
*any questions?
*to what extent do you agree with our findings? Did we miss anything or anyone?
*anything to add?

### 8.4.3 Data Commonalities

(Sashank Musti) – 20 MINUTES INCLUDING DISCUSSION

*Matrix distributed in advance.
Literature review of studies that document their analysis revealed that each one of the stakeholders may be interested in a number of data elements. Some of the broad areas are:
1) Socio demographics
2) Vehicle ownership and usage behavior
3) EV charging behavior
4) Attitudes and opinions towards new vehicle technologies.

***Socio demographics***

- Variables listed in the table are of interest to each stakeholder group and support their analyses. The table shows if these data elements are
  - Included in household travel surveys
  - If their focus is at regional or national level or customized according to need
  - Relevance to different stakeholder groups
  - Privacy concerns if any
- Variables range from home type and income level to residential and workplace location. A number of these variables are significantly relevant to most stakeholder groups. For example, residential location is important to all the stakeholders. Similarly, household income might be important for travel behavior analysis but has minimum relevance for utility companies.

***Vehicle ownership and usage behavior***

- Key variables in this category range from number and type of vehicles to vehicle use behavior

- Some of these variables are not collected in travel surveys due to budget and time frame constraints. But they can be collected in travel surveys depending on need.

***EV charging behavior***

- Since travel behavior surveys don't focus on EV usage or charging behavior they are not usually present in travel surveys.
- However, most of the data elements that are significant importance to other stake holder groups can be easily incorporated in travel surveys.
- For example, Idaho National Labs collected data elements to better understand EV charging behavior and OnStar does the same.

***Attitudes***

- Most of the attitudinal variables relating to EV adoption need responses from a strategic sample. Hence, these variables cannot be included in travel surveys that usually focus on random samples.

Overall, we have observed that there are data commonalities across different areas and stakeholder groups.

**Turn back to Tina for discussion.**

1) Any questions?
2) Costs – how do you fund the studies? Grants? Research funds?
3) Is the EV data collected only sharable when the technology becomes more acceptable? Are there any privacy concerns?

### 8.4.4 Collaboration Levels

*(Stacey Bricka) – 10 MINUTES INCLUDING DISCUSSION*

Research Objective: Confirm preliminary findings regarding research into shared data needs and interests between travel behavior and electric vehicle researchers. Discuss and identify a framework for better coordination of travel behavior data collection and accessibility across multiple stakeholder groups.

Present possible scenarios/levels of collaboration: Strictly a fact-finding mission. Trying to figure out lay of the land – where to start discussion. Spectrum of joint activities.

1. Lowest level – Communication. background, informal networking and information sharing, like this workshop. Just start the conversation – get to know regional agencies, data options, communication focused. Share existing data already collected.
2. Coordination. More structured communication –maybe at the association level (like TRB, SAE, EPRI?) Better communication of research going on, shared interest in research needs, collaborating on what needs to be done to help move us forward.

3. Cooperation – project add-ons – I know your data needs and add 3 questions to my survey, you know I'm gathering GPS and provide funds for larger, longer-term sample.
4. Full collaboration - Jointly develop and fund travel surveys that are redesigned to meet broader needs

*ask questions – where are we now? How define levels, what is needed for movement between levels? What type of institutional barriers do you see needing to be addressed?

Consider these questions if the topics do not come up during discussion
1) Would you be willing to collaborate on common data needs?
2) Is there a way to collaborate efficiently especially on collecting data elements that are expensive and have a long time frame (for example: panel data information on vehicle ownership behavior)?
3) Have you worked with people in other industries for such programs? What has your experience been?
4) Have you considered adding questions of interest to household travel surveys?

### 8.4.5 Identification of Priorities

*30 MINUTES*

Purpose of this meeting is not to solve the problem, but to identify what needs to be solved.
*facilitated discussion of what we need to know to move forward –

- should we move forward,
- what barriers or difficulties do we anticipate,
- where do we need more research to establish a solid framework,
- what are the low hanging fruit, …?

### 8.4.6 Final Comments

*15 MINUTES*
*give each a few minutes to give final comment?

*thank them for their time – next steps –

POLL - Anyone attending plug-in 2012 in San Antonio? We will have a team member there if you want to follow-up with any thoughts, or can email Stacey.

Developing problem statement –available by late August, if anyone is interested in reviewing? 2-4 page document.

We will follow-up with information about who DOT contact is and other ways to indicate support of the problem statement in the NCHRP process.

## 8.5 Stakeholder Workshop Minutes

### 8.5.1 Workshop #1 (Thursday) Minutes

***Introduction, Overview, Project Scope and Preliminary Findings***
The workshop opened with the moderator guiding introductions and provided an explanation of goals and objectives. The objectives included:

- Vetting preliminary research regarding the intersection of data needs between travel behavior and electric vehicle research
- Discussing whether and how some type of data sharing partnership might work, possible barriers, and what would need to be focused upon to make this work.
- Receiving input from the group on the priorities of the research needs identified.

The moderator then presented background information, including:

1. Information on the National Cooperative Research Program and funding source
2. The transportation data seen as most relevant to the discussion
3. What preliminary research is suggesting.

Following that explanation, the moderator then asked participants to take part in a poll on their familiarity with the NCHRP program.

- Forty percent of respondents were not familiar,
- 20 percent were somewhat familiar, and
- 40 percent were very familiar with the NCHRP program.

The moderator explained that the NCHRP program is a pooled research fund, and that research ideas usually come from a variety of sources, including the committees of the Transportation Research Board, various State DOTs, and the USDOT. The moderator stated that the team is hoping to develop a research statement for the 2014 research cycle, and that research project funding averages at $600,000.

The moderator asked how the participants fund their research activities. One individual stated that their activities are funded by USDOE through the alternatively fueled vehicle program. The individuals stated that they are primarily tasked with collecting data from vehicles.

***Transportation Data***
The workshop moderator stated, “In terms of traffic data, the regional transportation agencies collect passive data using GPS studies, tube counters, and Bluetooth readers. All that data is used to provide support to generate statistics on level of service, travel time, etc. Travel surveys provide insight on how people move through transportation systems. Data that is collected is fed into regional travel demand models to determine and estimate future demand of transportation services. We are currently transitioning to activity-based models, which are much more data intensive than typical models of the past.

The transportation secure data center (TSDC) provides a centralized, secure data source for individuals and groups.

For this project, we are trying to investigate where we can share data between the three different sectors. We started with a literature review of past activities and we combed through our contact list to find individuals who could be potential participants for our workshop."

The moderator then asked the participants four questions:

1. What is currently going on with data collection?
2. Where are the gaps in the data?
3. Who are the main players?
4. Are there similar perspectives across the different sectors?

Concerning the data gaps, the group felt that the lack of longitudinal data was a main concern. They also felt that identifying changes in travel behavior was an issue. Finally, the question of whether drivers experience range anxiety was an important question.

The moderator asked if any individuals had any questions, to which a participant responded, "The utility industry is seen as the gas station, or at least the gas advisor. Driving patterns should answer whether there is range anxiety. If nothing else, we need to focus on driving habits and seeing what types of cars people buy, whether they are pure electric vehicles or PHEVs. We are asking people what they driving and how they are driving. We are not doing any detail with travel surveys. We are trying to establish a baseline. How do you currently drive the car that the electric vehicle will replace? We are directed more toward the vehicle – not general, overall energy usage. We are less inclusive than what you guys [travel behavior modeling sector] are doing."

The individual added, "Of the people who have electric vehicles, we are trying to determine what people are driving and how they are driving. We are looking to get data from 8,000 EVs and 16,000 charging stations. Most of the chargers are 240-V Level 2 chargers with a few fast 480-V chargers. We are trying to ask the question: Where are people demanding to be charged? The primary focus of the project is to focus on the infrastructure that is wanted and needed. Ecotality is doing infrastructure work that is outside the scope of our project."

***Data Commonalities***

A moderator presented a matrix of common data elements that may exist across the different sectors. . The moderator identified four areas that the stakeholders may be interested in:

1. Socio-demographics
2. Vehicle ownership and usage behavior
3. EV charging behavior
4. Attitudes and opinions towards new vehicle technologies

The moderator commented that they "are not seeing a lot of research from the electric utility companies. Potentially, the research may be young and not as well developed as what we have seen from other sectors." Another moderator added "there is a difference between what people say that they do, and what they actually do."

A participant stated, “We typically ask people about fast charging, and they respond with overwhelming “Yes”, but when we do willingness-to-pay, people are not willing to pay for the infrastructure. Will people come if we build it?”

A moderator asked one of the participants if they had asked any questions regarding the costs of the infrastructure. They posited the idea that the public may not have an idea. The participant responded, “We have done research on willingness-to-pay with a regular car versus EV.”

Another respondent stated, “We can ask all of those questions hypothetically. With travel surveys, we can understand how people are traveling. We need to do a fusion of different data sources to come up with a net conclusive result. There are roughly 15,000 Nissan Leafs currently on the road. We need to have realistic expectations about the market.”

The moderator asked the respondent if the matrix captured the key elements. The respondent replied that, “You can never have enough data from households, such as income and education statistics. We typically ask people if they are willing to purchase an EV.”

The moderator presented the question “What Is the most important data element?”

- 25 percent of respondents felt socio-economics were most important,
- 50 percent indicated vehicle ownership and travel behavior,
- 25 percent identified charging behavior data, and
- None felt that either additional data or “other” were the most important element.

A respondent stated that they needed to collect data on market segmentation. Another respondent stated, “One of the reasons why I like to use GPS is the capability to passively collect data. Our travel surveys are commonly very burdensome to participants. We need to reduce the level of involvement for the respondents. People are so engrained with their cellphones – they don’t even bother with turning the GPS tracking feature off.”

***Collaboration Levels***

The moderator presented information regarding collaboration levels. The moderator wanted to confirm preliminary findings regarding research into shared data needs and interests between travel behavior and electric vehicle researchers. They also wanted to discuss and identify a framework for better coordination of travel behavior data collection and accessibility across multiple stakeholder groups.

The moderator presented possible scenarios/levels of collaboration in a fact-finding mission.

1. Lowest level – Communication. This includes background, informal networking and information sharing, like this workshop. Just start the conversation – get to know regional agencies, data options, communication focused. Share existing data already collected.
2. Coordination. This involves more structured communication –maybe at the association level (like TRB, SAE, EPRI). Better communication of research going on, shared interest in research needs, collaborating on what needs to be done to help move us forward.

3. Cooperation – project add-ons – I know your data needs and add 3 questions to my survey, you know I'm gathering GPS and provide funds for larger, longer-term sample.
4. Full collaboration - Jointly develop and fund travel surveys that are redesigned to meet broader needs

One of the moderators asked the group "What are the potential areas for collaboration between the three sectors? Could we identify any joint research needs that could be funded by multiple sources? We are trying to get the facts about a movement toward potential research that is beyond just ordinary communication." Another moderator followed-up with the question "Where are we on the pyramid?"

The first moderator responded, saying, "The coordination level would consist of getting TRB and different associations to cross-talk and formalize communication and sharing between the different sectors."

A participant stated, "Right now, there are no formal research channels between the three sectors. If I wanted to contact someone, it would be fairly difficult. In some respects we are not even at the communication level right now as we don't have any channels of communication established at least between regional governments (who are most often involved in relevant data collections) and private sector." Another participant stated that an associate "does presentations at energy-related conference. The people from MPOs and State DOTs do not go to energy-related conferences. The FHWA Value Pricing people and the congestion pricing community are not familiar with our secure data portal."

The moderator asked several participants if they would be interested in this. One participant stated, "If there is no other forum, what you are proposing could be seen as the early adopter stage. I started in the automotive industry, and now I am learning more about this through TRB. Getting down to the question, there are some real hurdles to collaboration. We have some data sharing agreements with 4-5 OEMs. The bad news centers on the OEMs being very protective of their own data. We have access to very raw data, but we would have to walk a very fine line if we ever used a repository such as the secure data center."

Another participant answered, "The only way to resolve this is to have everyone contribute during the data collection process." Yet another participant stated, "We haven't found a way to get quality data without getting the manufacturers involved."

The moderator asked "The fact that the EV market is small—is that a barrier?" A participant responded, "Getting a good sample size is difficult and we cannot do the typical travel survey. Mass market EVs and PHEVs have the potential for a lot of research in understanding how the vehicle is charged and how the electric utility can respond. The data is a means unto itself."

The moderator asked what the #1 barrier was going forward. A poll about what barriers individuals anticipated going forward received responses of

- Institutional – 50%
- Financial – 0%
- Privacy – 25%

- Custom data – 0%
- Other – 25%

A respondent stated, "The "silo-ing" of funding to conduct research does not typically mix. It is a major barrier." Another respondent stated, "I am worried data will become "balkanized" and will only be used and interpreted by academics. We should pursue it with people who are just analysts. We will be working with people who can actually attempt to solve problems."

One respondent stated, "the main obstacle is absence of a **forum** where all three sectors can exchange experiences and ideas." Still another respondent felt that "Just approaching the folks in the auto industry is fairly difficult. The auto industry is very self-centered. There is not a very collaborative approach within the industry. When we approached one auto manufacturer, they were originally just interested in selling cars – now they are coming to us with a bunch of questions about our research. There is definitely a research question to answer, and all of them are worthwhile. Idaho National Labs wants to coordinate our research needs with any interested organization. We do not need the auto industry to move forward with our research. If we can produce aggregate-level information from all of these demonstrations, then we can potentially share data."
A respondent added, "You want to have an efficient use of resources. There is an added benefit in making sure that data needs are met by each of the sectors."

***Closing Comments***
In closing, the moderator asked if any of the respondents would be attending the plug-in conference in San Antonio. One respondent replied in the affirmative.

A respondent stated, "This was a great discussion and there is a great potential for the future. The goal should be to get the research statement through the NCHRP." Another respondent stated that he did not have any closing comments, but "This is a worthwhile research project to pursue. One specific item that I did not mention before: You have to take stated preference data with a grain of salt; it is limited in its ability to describe what people actually do relative to real-world travel behavior and vehicle purchase data. You need to look at travel behavior and see potential areas for collaboration in research."

### 8.5.2 Workshop #2 (Friday) Minutes

***Introduction, Overview, Project Scope and Preliminary Findings***
The workshop opened with the moderator guiding introductions and provided an explanation of goals and objectives. The objectives included:

- Vetting preliminary research regarding the intersection of data needs between travel behavior and electric vehicle research
- Discussing whether and how some type of data sharing partnership might work, possible barriers, and what would need to be focused upon to make this work.
- Receiving input from the group on the priorities of the research needs identified.

The moderator then discussed background information, including:

1. Information on the National Cooperative Research Program and funding source
2. The transportation data seen as most relevant to the discussion
3. What preliminary research is suggesting.

Following that explanation, the moderator then asked participants to take part in a survey on their familiarity with the NCHRP program.

- 42.86 percent of respondents were not familiar,
- 42.86 percent were somewhat familiar, and
- 14.29 percent were very familiar with the NCHRP program.

The moderator explained that the NCHRP program is a pooled research fund, and that research ideas usually come from a variety of sources, including the committees of the Transportation Research Board, various State DOTs, and the USDOT. The moderator stated that the team is currently trying to submit a research statement for the 2014 research cycle, and that research project funding averages at $600,000.

The moderator asked the respondents if their research was funded through a certain program. One participant responded that they are a non-profit, and that they "work with vendors and suppliers through pooled sources. Advanced Energy usually applies for grant funding for their research. USDOE's Clean Cities is one such program."
Another participant stated that they "get pooled funds through the states" and "currently have a project with a national laboratory, and do not have the guaranteed funding that [another participant] currently receives."

***Transportation Data***
The moderator then asked participants if they were familiar with these types of data.

- None of the respondents were not at all familiar
- 75 percent were somewhat familiar
- 25 percent were very familiar

One of the participants asked what the main barriers were to getting 24-hour GPS data. The moderator responded that the barriers were "Money, time, and resources." The moderator stated that she did not "think anyone from the travel survey sector is happy with 24-hour data, but they realized that was the best they could get."

The participant stated that they received 300 data loggers for $55 per unit. Another participant stated that their main issue was "power management and extending the life of the units over our observation period." The moderator stated, "At the latest TRB meeting, we found that everyone is working on their own mobile app and not working together on the same thing. Market penetration with GPS-enabled smartphones is not great; we are currently pursuing a multi-mode approach to collecting data."

Another moderator asked if the participants agreed with what the research team had found. She asked if the research is limited in these fields. A participant stated, "We've used travel data extensively from the MPOs. However, most of the MPO data on the site is useless. I tried to use

data from one MPO and needed more details, so called that MPO directly, and they told me they weren't allowed to share it."

The moderator stated, "We are currently transitioning from the Minnesota site to the NREL secure data center. The site will actually include the raw datasets and associated documentation."

A participant responded, "I've been working with datasets from Caltrans and Puget Sound Regional Council (PSRC)."

***Data Commonalities***

A moderator presented a matrix of common data elements that may exist across the different sectors. The moderator identified four areas that the stakeholders may be interested in:

1. Socio-demographics
2. Vehicle ownership and usage behavior
3. EV charging behavior
4. Attitudes and opinions towards new vehicle technologies

The moderator asked if the research team had captured the correct information on the socio-demographic slide. A participant asked if it said "anything about the garage, or any physical home characteristics?" They also stated that they "typically look at property values." The moderator stated, "Property values are secondary data because we typically cannot ask that many questions in a survey."

Another moderator asked, "Are we capturing the right vehicle ownership data elements?" A participant stated, "I think for our studies, we do quarterly statistics that overlaps with the GPS data – such as getting information on battery temperatures and vehicle diagnostics. Data loggers are familiar limited; you need more detailed information on how people are using their vehicles. You need to understand how people adapt to the technology over time – such as discovering that their choice of charging station changes after a few months of initial use. You miss Level 1 charging data if you only capture data from the public charging stations."

A moderator asked if they had captured the key data elements. A respondent said, "Petroleum displacement and in-cabin vehicle temperature are critical data elements. Ambient temperatures are also fairly important. We need to answer: Will people still use outdoor stations in bad weather?"

***Collaboration Levels***

The moderator presented information regarding collaboration levels. The moderator wanted to confirm preliminary findings regarding research into shared data needs and interests between travel behavior and electric vehicle researchers. They also wanted to discuss and identify a framework for better coordination of travel behavior data collection and accessibility across multiple stakeholder groups.

The moderator presented possible scenarios/levels of collaboration in a fact-finding mission.

1. Lowest level – Communication. This includes background, informal networking and information sharing, like this workshop. Just start the conversation – get to know regional agencies, data options, communication focused. Share existing data already collected.
2. Coordination. This involves more structured communication –maybe at the association level (like TRB, SAE, EPRI). Better communication of research going on, shared interest in research needs, collaborating on what needs to be done to help move us forward.
3. Cooperation – project add-ons – I know your data needs and add 3 questions to my survey, you know I'm gathering GPS and provide funds for larger, longer-term sample.
4. Full collaboration - Jointly develop and fund travel surveys that are redesigned to meet broader needs

The moderator asked if the participants shared data outside of their group. A participant stated that they could not "release data without an agreement from the OEMs. With government funded contracts, you can place a stipulation that allows disaggregated data to be private, but ensures public aggregated data. Data with latitude and longitude variables can have issues with privacy. We look at the pressure of the gas pedal for energy use."
Another participant stated that they "asked our participants if we could put their GPS data online – and most of them agreed. I don't think privacy really mattered to them."

A moderator asked the group if they agreed that we are at the communication level. In addition, followed up asking, "Ideally, does it make sense to fully collaborate?" A participant stated, "This pyramid is an accurate description of the problem. We need to move through the pyramid by scaling it one level at a time. It may be difficult to get up to the top." Another participant stated, "Addressing institutional barriers are the hardest. I think it will be a serious challenge to acquire data from private companies." A third participant felt that, "For the energy and air quality sectors, we need second-by-second data along with engine characteristics. You will get into trouble with handling data from different sources – each collected because of different goals that are derived from various sectors and companies."

One participant stated they "have been successful in getting data from a number of different sources in order to understand how vehicles are actually used. All of the barriers: institutional, financial, privacy are just as important." Another felt that "Taking care of privacy is much easier than we have previously thought. We have removed specific latitude and longitude variables in our research and just assigned an aggregated regional code. Privacy is just a technical issue."

The moderator asked "Can you move forward without all of the participation of all of the sectors? Should we move forward, is this a worthwhile endeavor? The group discussed that the effort to collect data is significantly more useful than having nothing. What is the role of local governments? Getting good, not bad information is critical to government to ensure that good investments are being made. Some states and agencies are fragmented by nature. It makes sense to pull information from different technologies together. For example, UC Berkeley partnered with Nokia to collect data from smartphones – this is a good example of collaboration." A participant stated, "In one state, we are looking for data to help us identify where people would

stop along interstates to charge their vehicles. You need to capture data that is outside of urban areas."

The moderator asked, "What organization would take the lead in bringing everyone together?" One participant felt that "UC Davis seems to be the leader at the moment. They are looking at issues beyond the US border." They also identified that Plug-In America could be a possible organization. In addition, they felt that "Advanced Energy already has strong ties with charging companies, utilities, and government groups. We also have been doing evaluations on EVs for a while."

A moderator asked, "Because of the lack of industry organizations, should we build more toward a more formal cooperative arrangement?" A participant responded with a question, asking, "Could we get car industry input if we find a way for them to benefit?" Another participant stated, "We have a partnership with an auto manufacturer where we design part of our research for their benefit. The level of data that we are capturing can be put back into their models."

A third participant stated that they first "need to understand what their problems are before we reach out to the auto industry. All of that effort can be of direct benefit to their industry. For example, consider the safety impacts of EVs." They also felt that they were "100% behind the activities that pushes this ball forward."

***Closing Comments***

In closing, one participant stated, "I think it is great to reach out for a broad sample of data. I am a big fan of automating data collection using GPS. Using the can-bus within an automobile is a positive technological advancement to collect data."

Another participant was "very supportive of work in this topic. I have been a big supporter of the GPS add-ons for data collection. It would be good to have some participation."

A third participant conveyed "the frustration of getting good data in my earlier comments. It is my opinion that not enough data is currently out there. Having 10,000 households as the baseline for a research project is too small of a sample."

Finally, one last participant stated that he wanted "to plug-in the idea of having a shared site with aggregated data that is only used between a limited number of key players. I do believe that it is great to conduct research on this topic."

## 9.0 REFERENCES


Aultman-Hall, Lisa, et al. *Travel Demand and Charging Capacity for Electric Vehicles in Rural States: A Vermont Case Study. 91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.

CalCars. 2003. The California Cars Initiative 2003. Plug-In Hybrids, Palo Alto, California. Available at http://www.calcars.org.

Carlson, Richard Barney, Matthew G Shirk, and Benjamin M Geller. "Factors Affecting the Fuel Consumption of Plug-in Hybrid Electric Vehicles." *Fuel Cell* (2010). Print.

Chlond, Bastian, and Martin Kagerbauer. *Market Potential for Electric Vehicles from a Travel Behavior Perspective. 91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.

Davies, Jamie, and KS Kurani. *Households' Plug-in Hybrid Electric Vehicle Recharging Behavior: Observed Variation in Households' Use of a 5kwh Blended Phev-Conversion. 89th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2010.

Elgowainy, Amgad, et al. *Impact of Plug-in Hybrid Electric Vehicle Charging Choices in 2030. 91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.

Electric Power Research Institute. 2010. Characterizing Consumers' Interest in and Infrastructure Expectations for Electric Vehicles: Research Design and Survey Results. Report Number 1021285. Accessed from http://et.epri.com/publicdocuments.html

Gonder, J., et al. *Using GPS Travel Data to Assess the Real World Driving Energy Use of Plug-in Hybrid Electric Vehicles (PHEVs). 86th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2007.

Khan, Mobashwir, and Kara M Kockelman. "Predicting the Market Potential of Plug-in Electric Vehicles Using Multiday GPS Data." *Energy Policy* (2012): 1-9. Print.

Loiselle, Aaron, Jacek Rostkowski, and D Karman. "The Effect of Driving Conditions and Ambient Temperature on Light Duty Gasoline-Electric Hybrid Vehicles (3): Battery Energy." *SAE Technical Paper* (2010). Print.

MIT Energy Initiative Symposium. 2010. Electrification of Transportation System. Accessed from http://web.mit.edu/mitei/docs/reports/electrification-transportation-system.pdf

Morrow, Kevin. "Testing Activity Plug-in Hybrid Electric Vehicle Charging Infrastructure Review." *Power* (2008). Print.

Markel, T., K. Smith, and A.A. Pesaran. *Improving Petroleum Displacement Potential of PHEVs*

*Using Enhanced Charging Scenarios*. *Presented at EVS-24 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium.* Stavanger, Norway, 2009.

Moran, Kevin, and Brendan Foley. "Digital Maps, Connectivity and Electric Vehicles-Enhancing the Ev/Phev Ownership Experience." *Journal of Passenger Cars - Electronic and Electrical Systems* 3 (2010): 76-83. Print.

Musti, S. and K. Kockelman. 2011. Evolution of the Household Vehicle Fleet: Anticipating Fleet Composition and PHEV Adoption in Austin, Texas. *Transportation Research Part A* 45(8):707:720.

Pellon, Michael B., David K. Grover, and Margaret J. Eppstein. *An Agent-Based Model for Estimating Consumer Adoption of Phev Technology*. *89th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2010.

Simpson, A. *Cost-Benefit Analysis of Plug-in Hybrid Electric Vehicle Technology*. *Presented at the 22nd International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition (EVS-22).* Yokohama, Japan, 2006.

Smart, John, et al. "Electricity Demand of PHEVs Operated by Private Households and Commercial Fleets: Effects of Driving and Charging Behavior." *Energy* (2010). Print.

Tate, ED, MO Harpster, and Peter J. Savagian. "The Electrification of the Automobile: From Conventional Hybrid, to Plug-in Hybrids, to Extended-Range Electric Vehicles." *SAE International Journal of Passenger Cars - Electronic and Electrical Systems* 1 (2009): 156-66. Print.

Tate, E.D., and Peter J. Savagian. "The Co2 Benefits of Electrification: E-Revs, PHEVs and Charging Scenarios." *SAE World Congress* (2009). Print.

Tuttle, D. and K. Kockelman. 2012. Electrified Vehicle Technology Trends, Infrastructure Implications and Cost Comparisons. Proceedings of the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., 2012.

Vyas, Anant D, Danilo J Santini, and Larry R Johnson. *Plug-in Hybrid Electric Vehicles' Potential for Petroleum Use Reduction: Issues Involved in Developing Reliable Estimates by Plug-in Hybrid Electric Vehicles' Potential for Petroleum Use Reduction : Issues Involved in Developing Reliable Estimates*. *88th Annual Meeting of the Transportation Research Board.* 2009.

Zhou, Yan, Anant Vyas, and Danilo Santini. *Tracking National Household Vehicle Usage by Type, Age, and Area in Support of Market Assessments for Plug-in Hybrid Electric Vehicles*. *91st Annual Meeting of the Transportation Research Board.* Washington, D.C., 2012.