Transportation Technical Reference Manual:
Guide to Characterize the Savings, Benefits, and Costs of Transportation Efficiency Measures

June 2014

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This paper was researched and written by Justine Sears, Senior Analyst, and Karen Glitman, Director of Transportation Efficiency at the Vermont Energy Investment Corporation. The Vermont Energy Investment Corporation is a mission-driven nonprofit organization, founded in 1986, that is dedicated to reducing the economic and environmental costs of energy consumption through cost-effective energy efficiency and renewable technologies. Ms. Sears and Ms. Glitman are part of the organization’s Transportation Efficiency team.

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Introduction


While using standardized methodologies to measure the energy impacts and cost-effectiveness of efficiency programs is common practice in the electric and thermal energy sectors, this is not the case for transportation. As electric vehicles (EVs) spread nationwide, the electricity and transportation sectors have an increasing number of shared interests and an opportunity to learn from one another. One opportunity for knowledge transfer involves assessing the financial and environmental benefits of transportation measures, such as alternative fuel vehicles and fueling infrastructure, in the same way that energy utilities characterize efficiency measures and inform program development—namely, through a tool called the Technical Reference Manual (TRM). Inspired by this widely-used model, the National Association of State Energy Officials (NASEO) and the Vermont Energy Investment Corporation (VEIC) have developed the following Transportation TRM to characterize energy savings, environmental benefits, and financial costs of selected transportation efficiency measures and establish a framework for comprehensive and informed decision-making.


A Transportation TRM may be of interest to a variety of stakeholders, including those entities that already employ TRMs, such as utilities and Public Utilities Commissions (PUCs), as well as state energy and transportation planning agencies. The way that a Transportation TRM is refined and ultimately used will vary by end user and their objectives, whether for the design and implementation of efficiency programs or for policy and plan development.

Utilities

Electric, natural gas, and energy efficiency utilities may use a Transportation TRM to estimate the relative efficiency gains of measures such as conversions to electric and natural gas vehicles, as well as the installation of charging and fueling equipment. The development of a Transportation TRM enables the energy sector to view EVs as “mobile appliances” and thus assess their efficiency in much the same way that they do for appliances like washers and light bulbs in a conventional TRM.¹ A Transportation TRM could help to guide the optimal deployment of EVs, including through consideration of EV-specific rates and location and type of away-from-home charging stations (e.g., Level 2 240V charging vs. DC Fast charging). A proactive approach to EV deployment and infrastructure development, guided by a well-informed decision-making through a TRM, will ensure that grid impacts are minimized and environmental benefits fully realized. Strategies and approaches to efficiency vary among utilities, depending on whether they operate in a state that has undergone deregulation or one that decouples usage from profits, thus requiring the customization and refinement of the TRM on a market-by-market basis.

State Energy Offices

Although TRMs have traditionally been used in the regulated realm, they can also inform energy policy as it applies to transportation energy. Most SEOs include transportation energy in their scope, often focusing on alternative fuels, but not on broader efficiency measures, or a systems-level approach to reducing energy use and ensuring accessibility for all users. A Transportation TRM can guide policy and program development to create financing, incentives and/or state and local fleet conversion efforts. Importantly, many SEOs are not limited in the same way that utilities and PUCs may be regarding fuel switching; rather, for SEOs, a switch to a more efficient fuel or mode may simply represent optimal management of a state’s transportation energy portfolio.

¹ Fuel switching away from conventional vehicles and fuels to regulated fuels is a different scope of efficiency measure than is often considered by electric and natural gas utility efficiency programs. There are two approaches to measuring alternative fuel vehicle (AFV) efficiency: comparing the environmental and financial benefits of an AFV to a similar AFV (e.g., electric vehicle to
Public Utility Commissions

Entities that oversee utility efficiency programs, such as Public Utility Commissions (PUCs) and some State Energy Offices (SEOS), can use a Transportation TRM as a framework for regulatory decision-making. To date, transportation energy has largely been left out of the scope of energy planning, thus limiting the transportation sector’s engagement in energy efficiency and optimal least cost planning. As more of transportation is powered by regulated fuels, the opportunity to engage in such planning becomes a reality, facilitated by collaboration among state Departments of Transportation (DOTs), SEOs, and PUCs.

Transportation Planning Agencies

Transportation planning agencies, such as state DOTs and regional planning commissions, often lack a standardized means of conducting cost-benefit analysis or valuing externalities associated with transportation decisions. A TRM model would address this weakness and facilitate long-term planning that incorporates a full and accurate analysis of cost-effectiveness.

Defining Energy and Transportation Efficiency

The term “energy” is often limited to energy used for electric power, a regulated sector. However, energy is used for heat, some of which is regulated (e.g., natural gas) and some of which is not (e.g., heating oil), and for transportation. The vast majority of energy used in the transportation sector—gasoline and diesel—is not regulated, beyond certain safety and environmental requirements. In regulated sectors such as electric power and natural gas, prices, profits, and often efficiency programs are negotiated between utility companies and PUCs, and guided by state energy policy as set by the governor, legislature, and SEO. In unregulated sectors, such negotiations do not occur and the regulatory power of the PUC is limited.

However, in some states, including Vermont and Washington, transportation is included in the state’s statutory definition of energy. For instance, in the Vermont statutes that outline the power and duties of the Department of Public Service, energy is defined as:

“substances or processes used to produce heat, light, or motion, including but not limited to petroleum or other liquid fuels; natural or synthetic fuel gas; solid carbonaceous fuels; solar radiation; geothermal sources; nuclear sources; biomass; organic waste products; wind; or flowing water.” 2 (Emphasis added)

Thus, Vermont Department of Public Service (DPS) is empowered to oversee the implementation of efficiency programs, and energy policies as they apply to transportation, the same way that it does for regulated sources of energy. Similarly, in Washington statute, the policies and duties of the state energy office (under the Department of Commerce) contain a definition of energy that is inclusive of transportation.3 However, no similar definition is present in the statutes that apply to the Public Utility commission, suggesting that although transportation energy must be accounted for in the state’s energy policy, the PUC may not have regulatory power in this realm.

Definitions of energy vary in state statutes. Not uncommonly, transportation energy will be included in the scope of a state energy office but not within the regulatory power of a public utility commission, as in Washington. Vermont is an exception to this pattern- DPS also serves as the state energy office, providing the governor guidance on energy planning and policy issues.

Regardless of the mandate of its PUC, it is important for a state’s definition of “energy” to include that which is used to produce motion or transportation, whether regulated or unregulated. Within transportation, “efficiency” is used

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2 Vermont Statutes Annotated, Title 30 Chapter 5, V.S.A. § 201.
3 Revised Code of Washington, Chapter 43.21 F. 025.
most commonly in the context of fuel economy (miles per gallon), but it can also be used to measure the total amount of energy used to meet travel demand or access to services in a given area or by a given mode. Like estimates of vehicle fuel economy, which are estimates designed to capture a variety of real-world conditions, energy requirements of other modes of transport and other system-wide efficiency measures can be estimated. In this sense, long-term transportation efficiency is a systems-level approach to planning that aims to minimize the energy required to meet travel demand.

**COST-EFFECTIVENESS SCREENING AND LEAST COST PLANNING**

Cost-effective efficiency measures are those that reduce energy consumption and yield a positive net present value (NPV) over the average useful lifespan of a measure. Once potential efficiency measures have gone through a cost-benefit analysis or screening process, those that are deemed cost-effective and reduce energy consumption are included in a TRM. The TRM includes all algorithms, assumptions, and default values used to estimate the savings associated with each efficiency measure. The first TRM was compiled in 2001 and now includes hundreds of efficiency measures, all of which have been screened for cost effectiveness and energy savings. Efficiency measures that are determined to be cost-effective and reduce energy consumption may be included in a utility’s TRM and may also be eligible for financial incentives through utility energy efficiency programs.

The comprehensive approach to assessing efficiency and cost effectiveness provided by a screening tool and TRM would enable meaningful and consistent comparison among transportation efficiency measures, forming the basis of least-cost planning and informing potential incentive programs such that they maximize overall societal benefit. Least-cost planning is historically practiced in the electric sector and long-term integrated resource plans are required of utilities in many states (Wilson and Biewald 2013). In some areas, efficiency utilities and programs have been designed and mandated to reduce consumption of specific regulated energy sources. Least-cost planning is contingent upon a comprehensive cost-benefit analysis to identify cost-effective measures and programs. A long-term approach to reducing financial and environmental costs of transportation energy use thus requires a methodology to assess the full cost and benefit of transportation efficiency measures (and the full cost and benefit of baseline, business-asusual practices). An earlier effort to apply a utility cost-effectiveness screening test to transportation efficiency can be found in Sears et al. 2013.

Potential transportation efficiency measures may fall into three broad categories:

- Replacement of an existing vehicle with a more fuel efficient vehicle.
- Fuel switching (from gasoline or diesel to electric or natural gas, or other types of alternative fuel vehicles),
- Transportation mode switching (from single occupancy vehicle to car pool, transit, bicycle, or foot).

There are a number of challenges to applying least-cost planning methodologies to transportation efficiency measures, arising largely out of the fact that few of the costs associated with transportation energy use are included in the price of gasoline or diesel, and the costs and benefits of many transportation efficiency measures are not easily monetized. However, a screening and TRM process will help to standardize this analysis, maximizing overall societal benefit.

**FUEL SWITCHING**

Efficiency measures that entail fuel switching from gasoline or diesel to a regulated fuel may present a problem for some utilities. An example of a fuel switching efficiency measure is the replacement of conventional vehicles powered by gasoline or diesel with alternative fuel vehicles powered by electricity or natural gas. Although these

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4 TRMs are in use across the country, including in Pennsylvania, Arkansas, Massachusetts, Illinois, Rhode Island, and Ohio.
measures may offer efficiency gains on a Btu/mile basis, energy cost savings, and reduced environmental impacts relative to conventional vehicles, they increase the use of the regulated energy. This resulting increased consumption of the regulated energy may conflict with the goals of most efficiency utilities and programs. While fuel switching may be an issue, particularly in states that have decoupled revenue from usage, it also provides utilities and PUCs an opportunity to reassess current revenue calculations. Further, fuel switching highlights the need for a broader view of efficiency, limited not just to a single fuel source but overall energy use and greenhouse gas (GHG) emissions.

A transportation TRM can serve to ensure that load growth in regulated fuels is controlled and that efficiency and environmental gains from fuel switching are maximized. The TRM can be used to identify efficiency measures that will optimize the deployment of commercially available efficient electric or natural gas vehicles and efficient charging or fueling infrastructure. A more inclusive cost-benefit analysis that adequately values the variety of benefits of alternative fuel vehicles, such as reduced peak load, and reduced generation and transmission costs, will facilitate utility participation in their deployment. In addition, rate design can direct increased demand for regulated energy from alternative fuel vehicles to occur during off-peak hours, serving to flatten the overall load profile. If it proves too difficult in the short term to include measures that build load in utility efficiency programs, utilities may approach electric vehicles (EV) as large “mobile appliances”, and apply similar tests and programs as those historically used for other appliances. Further, unlike most appliances, EVs offer flexibility in potential use of smart or managed charging measures, ancillary services, and potential vehicle-to-grid or vehicle-to-building capability.

MODE SWITCHING
Traditionally, transportation funding and planning have focused on infrastructure design and maintenance rather than on energy consumption. Planning protocols rely on travel demand models which generally use metrics associated with travel time, congestion, and safety. Further, transportation planning is often focused on optimizing infrastructure for automobiles. Planning for other modes of travel such as transit, bicycling, and walking may not figure as prominently. With no clear means to assess the long-term cost of projects, especially inclusion of externalities, it is difficult for the transportation sector to engage in least-cost planning.

The wide variation in energy efficiency (measured in Btus per passenger mile) across transport modes and fuels highlights the need for greater focus and consistency in measuring transportation efficiency (Figure 1). A primary means of travel in the United States is through one of the least efficient modes available—conventional single occupancy vehicle—leaving much room for improvement in the overall operational efficiency of our transportation system. Travel demand models generally use metrics associated with travel time, congestion, and safety, but the boundaries used in modeling efforts can vary widely. Further, outputs of such models are often auto-centric, focusing on vehicle miles traveled (VMT) at the expense of non-auto-based measures (e.g., transit, bicycle, and pedestrian infrastructure). Additionally, behavioral aspects to travel and transportation energy use present both challenges and opportunities for improved transportation efficiency, including lifestyle choices and habits around walking and physical activity.
Approaches to Measuring Cost-Effectiveness

In the electric and thermal sectors, efficiency measures are assessed for cost-effectiveness using a cost-benefit analysis. There are a variety of tests available to assess cost-effectiveness, including: measuring the impact on rate-payers, quantifying the cost-effectiveness for utilities, and accounting for the total societal benefit by including externalities such as greenhouse gas (GHG) emissions and grid system reliability. Broadly, approaches to measuring the cost-effectiveness of energy efficiency measures include the following test methods:

1. The Total Resource Cost, which includes costs to society and the consumer,
2. The Societal Cost, which includes externalities not captured by market prices and non-energy benefits (e.g., avoided health costs, climate impacts, water usage).
3. The Program Administrator Cost, which calculates the cost of operating an efficiency program.
4. The Participant Cost, which estimates long term benefits to the consumer, accounting for lifetime costs, including maintenance and installation fees, and any available incentives.
5. The Rate-payer Impact, which examines lost revenue to the utility from reduced energy consumption achieved through greater efficiency (Energy Center of Wisconsin 2009). For efficiency measures that may alter patterns of use, any changes in the timing of demand must be considered (peak vs. off peak), in addition to overall energy use. For example, for EVs, there is some concern around the timing of charging and effects that widespread EV charging may have on peak load in areas with high EV penetration.

A particular cost-effectiveness test method is generally mandated through regulation and changes require PUC or Public Service Board approval. The sections below include a brief explanation of the major types of tests and our rationale in utilizing the Societal Cost test in this Transportation TRM.

TOTAL RESOURCE COST

The Total Resource Cost test is among the more common approaches to screening efficiency measures, though regulators may require a utility to perform more than one type of test (CPUC 2001). In recent years, these tests have received criticism for failing to value non-energy benefits properly. According to some critics, screening tools ignore or undervalue the benefits of efficiency measures while accounting for all of their costs, including incremental costs.
of installation and administrative program costs, which puts these measures at a disadvantage relative to business-as-usual scenarios (Neem and Kushler 2010). Despite this growing school of thought, capturing non-energy benefits remains challenging, as benefits are not easily quantified or may be highly variable. This challenge is especially pronounced in transportation cost-benefit analysis since many of the externalities and benefits associated with transportation efficiency measures are not energy-related, including health impacts of tailpipe emissions and active transportation, and quality of life impacts of bicycle and pedestrian infrastructure.

**PROGRAM ADMINISTRATOR COST**

Another test of cost-effectiveness test method is the Program Administrator Cost Test (PACT). A PACT considers only the costs and energy savings to the utility, and thus to the rate payers, and offers incentives based on these values. Although externalities can be included, non-energy benefits are not valued. A PACT leaves it to the consumer to judge the cost-effectiveness of a given measure. Incentives are available for a given measure and if consumers are willing to pay any additional amount required, they can. This type of test may be particularly relevant for the transportation sector, because many of the non-energy benefits of efficiency measures are difficult to quantify and highly localized or individualized. For instance, when screening electric vehicles, vehicles with a larger electric range may have a lower operating efficiency (kWh/mile) because the vehicle battery is heavier. However, the convenience afforded by this longer range may be what tips consumers’ preference for an EV over a conventional vehicle.

Many screening tools currently in use, such as those employed by some energy efficiency utilities, do not capture the increased convenience of a product, only the decreased electrical usage. A PACT may resolve this discrepancy. While the PACT approach to valuing efficiency measures may eliminate the difficulty in valuing non-energy benefits, this approach would not facilitate a true least-cost approach to electricity or transportation planning since lifetime costs are not captured.

**COMPARING AND CONTRASTING APPROACHES**

The screening tools used to conduct cost-effectiveness tests usually generate two primary outputs: NPV of the proposed efficiency measure and net societal benefits accrued over the measure’s lifetime.

- The NPV of the proposed efficiency measure presents savings in current dollars, accounting for inflation.
- The net societal benefit or benefit-to-cost ratio accrued over the measure’s lifetime is the ratio between the total benefits derived from the measure and the total cost. A societal benefit of less than one indicates that the NPV of the proposed measure is negative and not cost effective (and thus would not be included in a TRM nor be eligible for incentive programs).

When evaluating the cost-effectiveness of a utility energy efficiency program, the NPV and benefit-to-cost ratio may vary based on the test used. In a 2008 report, the National Action Plan for Energy Efficiency estimates that the benefit-to-cost ratio of the Southern California Edison Residential Energy Efficiency Incentive Program ranges from 0.63 under the Ratepayer Impact Measure to 9.91 under the Program Administrator Cost Test (as demonstrated in Table 1). The Ratepayer Impact Measure shows that the value of energy savings for the utility is less than the amount of reduced revenue and cost to run the program. In contrast, the high values of the Participant Cost Test and Program Administration Cost Test indicate that energy savings are worth much more than any costs to customers or program costs to the utility. This range indicates that cost-effectiveness of a given measure varies widely, depending on the boundaries of the test. The key takeaway from this exercise is that it is not enough to conclude that a given product or program is cost-effective or cost-ineffective, but it must be specified for whom (society at large, the utility, the customer/participant, all ratepayers, etc.).

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5 For example, Efficiency Smart, which operates in Ohio and Pennsylvania, the DC Sustainable Energy Utility, which serves the District of Columbia, and Efficiency Vermont.
TABLE 1. SUMMARY OF COST-EFFECTIVENESS TEST RESULTS  
(SOUTHERN CALIFORNIA EDISON RESIDENTIAL ENERGY EFFICIENCY INCENTIVE PROGRAM)

<table>
<thead>
<tr>
<th>Test</th>
<th>Net Present Value</th>
<th>Benefit-Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCT</td>
<td>$252 million</td>
<td>7.14</td>
</tr>
<tr>
<td>PACT</td>
<td>$168 million</td>
<td>9.91</td>
</tr>
<tr>
<td>RIM</td>
<td>-$109 million</td>
<td>0.63</td>
</tr>
<tr>
<td>TRC</td>
<td>$143 million</td>
<td>4.21</td>
</tr>
<tr>
<td>SCT</td>
<td>$143 million</td>
<td>4.21</td>
</tr>
</tbody>
</table>

**OUR APPROACH**

In this TRM, we use the Societal Cost Test (SCT) to fully assess the costs and benefits of transportation efficiency measures to both consumers and society. The SCT may be the most accurate option for evaluating transportation efficiency measures because the externalities associated with baseline transportation measures are sizable. For instance, the climate and health impacts of tailpipe emissions are generally not included in gasoline and diesel prices or elsewhere in the market, and it is widely recognized that current transportation fuel taxes are insufficient to cover the cost of infrastructure maintenance.

This document provides assumptions, default values, and equations used to calculate the energy and cost savings of transportation efficiency measures. The measures included in this manual will not necessarily pass the screening process in all locations. The goal of this document is to provide a framework and some basic data for such screening. The computations utilize national averages (of fuel costs, GHG impacts, etc.). A more customized assessment of efficiency measures should replace these generic inputs and estimates of deemed savings with inputs specific to the state or location of interest.

**ASSESSING TRANSPORTATION EFFICIENCY**

The scope of costs associated with transportation efficiency measures considered are presented in Table 2. These measures may include switching to a more efficient gasoline or diesel-powered vehicle, a fuel switch from a conventional vehicle to natural gas or electric vehicle, an upgrade from a Level 1 to Level 2 electric vehicle supply equipment (EVSE), or a mode switch from single occupancy vehicle to carpool or transit. In our analysis we account for costs to the consumer, utility, and society, although the costs ultimately included in an analysis may vary by end-user. For instance, electric utilities may not be able to consider efficiency gains resulting from fuel switching (e.g., a switch away from a gasoline-powered vehicle to an electric vehicle), although they may be able to consider electric efficiency gains achieved through EVSE infrastructure.

**TABLE 2. SCOPE OF CONSUMER, UTILITY, AND SOCIETAL COSTS CONSIDERED IN ASSESSMENT OF TRANSPORTATION EFFICIENCY MEASURES**

<table>
<thead>
<tr>
<th>Consumer costs</th>
<th>Utility Costs</th>
<th>Societal Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price of efficiency measure relative to non-efficient option</td>
<td>Impact on peak load</td>
<td>GHG emissions</td>
</tr>
<tr>
<td>Operation and maintenance, inc. energy costs (electricity, gasoline, natural gas, etc.)</td>
<td></td>
<td>Health impacts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congestion impacts (travel time and reliability; relevant for mode switching measures)</td>
</tr>
</tbody>
</table>

Major assumptions underlying this TRM’s calculations are summarized in Table 2 and appear in greater detail in the accompanying spreadsheets. Generally, national averages are used to ensure applicability for a wide range of

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6 In California, avoided costs of emissions are included in both the Total Resource Cost Test and the Societal Cost Test.
geographies, but these values can be substituted with local data where available. The assumptions used in our calculations include energy prices, vehicle operating costs, societal costs of externalities such as GHG emissions and emissions health impacts, and EV charging infrastructure, as explained in Table 3. This list is by no means exhaustive and should be expanded and refined as more transportation efficiency measures are assessed, including compressed natural gas vehicles and fueling infrastructure. Energy prices (gasoline, diesel, electricity, and natural gas) are reported as national averages and can be found in the accompanying spreadsheet (see ‘EIA 2013 energy price forecasts.xlsx’). It is important to note that there is more uncertainty about future natural gas and petroleum prices, relative to electricity price. Assessments of transportation projects involving these fuel types may thus be more complex than those for electric energy efficiency projects.

Avoided electricity costs include the forecasted energy costs that would have occurred without the proposed or implemented efficiency measure and avoided capacity costs.

### TABLE 3. MAJOR ASSUMPTIONS AND DATA SOURCES USED IN ASSESSING TRANSPORTATION EFFICIENCY MEASURES

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of diesel, 2014&lt;sup&gt;1&lt;/sup&gt;</td>
<td>$24.22/MMBtu</td>
<td>EIA Annual Energy Outlook, 2013</td>
</tr>
<tr>
<td>Price of electricity, 2014&lt;sup&gt;1&lt;/sup&gt;</td>
<td>$33.01/MMBtu</td>
<td>EIA Annual Energy Outlook, 2013</td>
</tr>
<tr>
<td>Avoided electricity costs</td>
<td>$0.10/kWh</td>
<td>Wilson 2013</td>
</tr>
<tr>
<td>Gasoline CO&lt;sub&gt;2&lt;/sub&gt; emissions</td>
<td>19 lbs/gallon</td>
<td>EPA 2013</td>
</tr>
<tr>
<td>Diesel CO&lt;sub&gt;2&lt;/sub&gt; emissions</td>
<td>22 lbs/gallon</td>
<td>EPA 2013</td>
</tr>
<tr>
<td>Electricity GHG emissions, 2013&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td>0.65 tons/MWh</td>
<td>EPA 2013</td>
</tr>
<tr>
<td>Cost of GHG emissions</td>
<td>$100/ton CO&lt;sub&gt;2&lt;/sub&gt; eq.</td>
<td>Synapse Energy Economics 2013</td>
</tr>
<tr>
<td>Health costs of vehicle emissions</td>
<td>$0.06/vehicle mile traveled</td>
<td>McCubbin and Delucchi (2011)</td>
</tr>
<tr>
<td>Health costs of electricity generation&lt;sup&gt;1&lt;/sup&gt;</td>
<td>$0.07/kWh</td>
<td>Machol and Rizk 2013; see Table 3</td>
</tr>
<tr>
<td>Annual vehicle miles traveled&lt;sup&gt;1&lt;/sup&gt;</td>
<td>10,650</td>
<td>FHWA 2012</td>
</tr>
<tr>
<td>Annual EV miles traveled&lt;sup&gt;1&lt;/sup&gt;</td>
<td>9,000</td>
<td>EV Project 2013</td>
</tr>
<tr>
<td>Cost of Level 1 EVSE and installation</td>
<td>$500-$1,000</td>
<td>Vendor estimates</td>
</tr>
<tr>
<td>Cost of Level 2 EVSE and installation</td>
<td>$1,200-$1,800</td>
<td>Vendor estimates</td>
</tr>
<tr>
<td>Cost of Level 2 EVSE with ability to charge users a fee&lt;sup&gt;3&lt;/sup&gt;</td>
<td>$7,000-$21,000</td>
<td>Vendor estimates</td>
</tr>
<tr>
<td>Cost of DC Fast Charging EVSE</td>
<td>$35,000-$125,000</td>
<td>Vendor estimates</td>
</tr>
</tbody>
</table>

<sup>1</sup>National average  
<sup>2</sup>Local value should be used due to high geographic variation  
<sup>3</sup>For non-residential public charging

Other factors considered in utility calculations of efficiency measures may include effects of spillover and free ridership. The former, spillover, refers to the adoption of efficiency measures not included in the program or incentive. The latter, free ridership, refers to savings that would have occurred even without the program. Often, these effects are assumed to be 1:1 and cancel one another out. Accurate measurement of these effects would require, at a minimum, surveying program participants. Due to lack of data, these factors are generally not accounted for in this document but they are a critical consideration for future analyses.

### ACCOUNTING FOR EXTERNALITIES

The primary externalities included in this Transportation TRM are the societal costs of GHG emissions and health impacts of vehicle tailpipe emissions. Although there is no federal regulation of carbon at present, we suggest a cost of $100 per ton of carbon dioxide equivalent (CO<sub>2</sub> eq.), the price estimated in the New England Avoided Energy Supply Cost Report (Synapse Energy Economics 2013). No federal compliance carbon market exists in the United
States, so the proposed cost is meant to account for the externalities associated with global climate change (including increased extreme weather events, altered weather patterns, and rising sea levels) and is derived by estimating the cost of reducing emissions to “sustainability levels.”\(^7\) Measures achieving avoided GHG emissions are thus credited $100/ton CO\(_2\) eq., while measures increasing such emissions are penalized.\(^8\)

The health costs associated with vehicle emissions are assumed to be $0.06/mile, a mid-range of estimates reported by DeLucchi and McCubbin (2011) in their review of transportation externalities, adjusted for inflation.\(^9\) These costs include health care costs of diseases and health problems aggravated and caused by local motor vehicle tailpipe emissions, including nitrogen dioxide (NO\(_2\)), ozone (O\(_3\)), carbon monoxide (CO), and particulate matter (PM). Future analysis could consider the geographic variation in exposure to tailpipe emissions.

The health impacts of electricity generation are estimated to be $0.07/kWh, on average for the nation in 2014, but more accurate estimates can be derived based on the particular mix of generation in a given location (available through the EPA database eGrid: [www.epa.gov/egrid](http://www.epa.gov/egrid)), and the values in Table 1. Estimates of the monetized costs of health impacts from electricity generation were only available for fossil fuels (coal and natural gas). Health costs to humans associated with hydropower and other renewable sources of electricity generation are generally thought to be minimal, although the noise impact from wind installations is still being evaluated.

### Table 4. Projected 2014 US Electricity Generation by Source and Associated Health Impacts from Emissions

<table>
<thead>
<tr>
<th>Energy source</th>
<th>% Generation (EIA 2013)</th>
<th>Estimated cost of health impacts (Machol and Rizk 2013)(^{10})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>39%</td>
<td>$0.19/kWh</td>
</tr>
<tr>
<td>Natural gas</td>
<td>27%</td>
<td>$0.015/kWh</td>
</tr>
<tr>
<td>Nuclear power</td>
<td>19%</td>
<td>unavailable</td>
</tr>
<tr>
<td>Renewables (wind, solar, biomass, hydropower)</td>
<td>13%</td>
<td>unavailable</td>
</tr>
<tr>
<td>Weighted national average</td>
<td></td>
<td>$.07/kWh</td>
</tr>
</tbody>
</table>

### Factors to Consider in Future Analyses

There are other costs and benefits that can be added as the screening and TRM processes are developed for transportation, including the health benefits of active forms of transportation, quality of life benefits associated with bicycle and pedestrian infrastructure, and benefits to property values gained through proximity to transit, bicycle, and pedestrian infrastructure. Future analysis may also consider the health care costs associated with motor vehicle crashes, as a mode switch away from personal vehicles may achieve cost savings through avoided crash-induced health care costs.

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\(^7\) As a point of reference, the California cap and trade program’s price per ton of CO\(_2\) eq. has varied from about $23 to $11 between 2012 and 2013 (California Carbon Dashboard).

\(^8\) We do not account for GHG emissions associated with methane release at hydroelectric dams, although there is growing evidence that these emissions from hydroelectric dam drawdowns can be sizable (see Hertwich 2013, Fearnside 2004, among others). As this research develops these emissions should be included in future analyses.

\(^9\) DeLucchi and McCubbin report 8 estimates of health impacts (2006 dollars) per passenger mile traveled from a variety of peer reviewed studies. Average vehicle occupancy was assumed to be 1.6. We converted their mid-range estimate of $0.033 per passenger mile traveled to cost per vehicle mile traveled: $0.054. This value was then adjusted for inflation to 2013 dollars using the Bureau of Labor Statistics Consumer Price Index, to arrive at our estimate of $0.06 of health impacts per vehicle mile traveled. Future analyses should consider health impacts on a per kilogram basis, rather than per vehicle mile traveled, due to continuing improvements in engine design and fuel quality.

\(^{10}\) Includes SO\(_2\), NO\(_x\), and PM emissions.
In addition, research has shown sizable costs associated with noise generated from motor vehicle use. Noise damage costs arise from reduced home values in affected areas. However, it is a challenge to reliably characterize these costs nationally, or even much beyond the local level. Accurate estimates of noise damage are difficult due to local variation in ground cover and structures that may mitigate such damage. DeLucchi and Hsu (1998) estimate that noise costs of motor vehicles range from $40 million to $5 billion annually in 1991 dollars. They further provide estimates of noise damage by road type (major arterial, interstate, and local roads) that could guide future efforts to account for this externality.

In addition, there may be substantial financial and grid resiliency benefits resulting from EV vehicle-to-grid interoperability, including demand response and load balancing effects of EV night-time charging. With a large enough volume of EVs and provisions for aggregation, these vehicle batteries may have the capability to serve as energy storage units and perform frequency regulation for the electric grid or residences and other buildings. The all-electric Nissan Leaf is already used for demonstration vehicle-to-home energy systems in Japan.

Widespread nighttime charging of EVs could serve to balance overall load. If base load is approximately even during the day and night, the operational efficiency of the generating system is improved. When generators drop load in the evening, there is an efficiency loss of “turn down”. In order to be included in a cost-benefit analysis, a monetary value would need to be attached to these grid services. Research is currently underway by a variety of entities in this field, including the University of Delaware’s Center for Carbon-free Power Integration and the National Renewable Energy Laboratory. With metering on EVSE units or directly from the vehicle to the utility meter through use of Advanced Meter Infrastructure (AMI), individual EVs could participate in demand response programs. The primary value of such programs is derived from avoided capacity costs, which will vary by utility area (CPUC 2010). Avoided capacity costs in New England are valued at $79.88/kW-year (Synapse 2013). However, at present, the use of EVs in demand response programs is only theoretical and there is some concern that using EVs in this manner could void the manufacturer’s warranty.

Future transportation efficiency measures to consider include the bundling of transportation and electricity measures, such as electric vehicles and residential photovoltaic solar arrays. Bundling of this sort will facilitate a transition to renewably powered transportation and may increase the cost-effectiveness of both transportation and electric efficiency measures.

**GEOGRAPHIC AND TEMPORAL VARIATION IN EXTERNALITIES**

The associated energy, financial, and environmental benefits of efficiency measures will vary with location, most notably GHG emissions and health impacts associated with electricity generation. In this document we present national averages. The accompanying spreadsheet provides additional data sources that can be used to modify calculations for other locations. The Environmental Protection Agency compiles the database eGrid, which provides sub-region specific emissions estimates. Alternatively, if the electricity mix is known, the associated emissions factor and health costs can be calculated using Table 3 and a $100/ton of CO$_2$ eq.

In addition, because the mix of sources used to generate electricity is expected to change over time, cost-benefit analysis can account for this change, which will affect both estimated health costs and GHG emissions. A forecast of the national generation fuel mix is available through the EIA and is included in the accompanying spreadsheet (EIA 2013).

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11 See NASEO 2013 Review of Utility IRP Scans. Some utilities are projecting that up to 6% of demand will come from EV charging by 2030.

12 See: [http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html](http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html)
**NON-ENERGY BENEFITS**

Some utility screening tools also include a non-energy benefits adder, a deemed value that is added to the estimated benefits of the measure being screened. The adder is intended to capture benefits that may otherwise be excluded from the tool’s characterization of savings and societal benefit. In buildings, non-energy benefits may include increased comfort resulting from weatherization efforts or increased convenience of using a programmable thermostat. In the screening of transportation efficiency measures, non-energy benefits may include some of the quality of life factors discussed above in the “Factors to Consider in Future Analyses” section.

**ASSISTANCE FOR LOW INCOME HOUSEHOLDS**

An additional adder can be included to encourage efficiency measures that benefit low income populations. In the case of transportation, a special effort should be made to target and implement such measures to ensure an equitable deployment and distribution of benefits. Transportation costs make up a significant portion of American household budgets, second only to housing costs, and similar to other energy-related costs, the cost burden grows as income declines (CHP and CNT 2012). In 2011, home energy and utility expenditures made up 6% of average household annual income and 23% of average low income household income. In contrast, transportation costs averaged 16% of overall household income and 33% of annual income in low income households (Figure 2). To alleviate this dynamic, it is common for utility efficiency programs to include low-income-targeted elements, although these programs may be less cost effective from a screening perspective than other efficiency measures.

**FIGURE 2. ANNUAL HOUSEHOLD EXPENDITURES ON ENERGY AND TRANSPORTATION  
(BUREAU OF LABOR STATISTICS 2011)**

Despite the disproportionately large burden that transportation costs present to low income households, there are few programs designed to defray these costs. Implementation of a standardized screening process in transportation planning could facilitate such programs and demonstrate their benefits. For instance, while public transit is often criticized for failing to meet costs through fares alone, it meets crucial mobility needs of those who either cannot afford their own vehicle or are unable or choose not to own one, including the elderly, young, and disabled.

In addition, although the upfront cost of EVs is generally higher than equivalent conventional vehicles, the overall lifecycle, fuel, and maintenance costs of these vehicles is considerably lower. As EVs enter the used car market and the price continues to drop with improved battery technology and increased production, they will become more affordable. The price of EVs continues to fall and available state and federal tax incentives help to make these vehicles more affordable. A crucial aspect of making EVs available to low income families will be outfitting multi-family residences with charging infrastructure. Although assigned parking spaces and individual apartment metering remain a challenge, programs and outreach to multi-family housing are needed.
The following sections outline three transportation efficiency measures within the scope of energy, environmental, and financial benefits described in Tables 2 and 3. These measures do not yet account for geographic variation, non-energy benefits, or impacts on low income populations, but these refinements can be incorporated as the Transportation TRM develops and is adapted for specific locales. To illustrate, Appendices C, D, and E include customized TRMs for the state of Utah, the Burlington Electric Department, and a Vermont distribution utility.
Glossary

**Baseline**: standard equipment or operating procedure, business as usual in absence of an efficiency program.

**Coincidence Factor**: the fraction of connected load expected to coincide with a particular system peak period, including summer, winter and spring/fall peak periods.

**All-Electric Vehicle (AEV)**: a vehicle that is powered exclusively by electricity

**Electric Vehicle Supply Equipment**: the infrastructure used to charge the batteries of plug-in electric vehicles (AEVs and PHEVs)

**Full Load Hours**: the equivalent hours that equipment would need to operate at its peak capacity in order to consume its estimated annual kWh consumption (annual kWh/connected kW).

**Free Ridership**: the fraction of gross program savings that would have occurred despite the program.

**Internal combustion engine (ICE)**: an engine in which fuel combustion occurs in a chamber.

**Lifetime**: the number of years that new high efficiency equipment is expected to function; may be based on engineering lives or equipment warranties.

**Line Loss Factor**: the marginal electricity losses from the generator to the customer - expressed as a percent of meter-level savings. The energy line loss factors vary by period. The peak line loss factors reflect losses at the time of system peak, and are shown for three seasons of the year. Line loss factors are the same for all measures.

**Load shape**: estimated proportion of energy use, seasonally; includes percentage of energy use (for baseline or efficiency measure) for winter peak, winter off peak, summer peak, and summer off-peak

**Operating Hours**: the annual hours that equipment is expected to operate.

**Persistence**: the fraction of gross measure savings obtained over the measure life. Persistence factors may decline with measure life due to reduced operating efficiency of equipment and may be adjusted as needed.

**Plug-in Hybrid Electric Vehicle**: a vehicle that may be powered by both electricity drawn from the grid and a gasoline-powered motor.

**Spillover**: savings attributable to the program, but generated by customers not directly participating in the program.
**Transportation Efficiency Measures**

**ALL-ELECTRIC VEHICLE**

**Definition of Efficient Equipment:** A vehicle that is powered exclusively by electricity

**Definition of Baseline:** Gasoline-powered internal combustion engine vehicle

**Description:** The operating efficiency of all-electric vehicles (AEVs) is greater than 3 times that of conventional internal combustion vehicles and the tailpipe emissions are zero. On average AEVs achieve an operating efficiency of 901 Btu per mile while conventional vehicles achieve an operating efficiency of 4,696 Btu/mile.

**Deemed Annual Energy Savings:** 34.2 MMBtu per vehicle per year

**Assumptions and supporting calculations**
- Annual AEV miles traveled: 9,000\(^{13}\) (slightly lower than the national average of 10,650 miles\(^{14}\))
- Average fuel efficiency of new conventional vehicles sold, model year 2013: 24.7 miles per gallon (4,696 Btu per mile)\(^{15}\)
- Average efficiency of AEVs available, model year 2013: 3.33 miles per kWh (901 Btu per mile)\(^{16}\)
- Travel patterns are assumed to be the same for the conventional and all-electric vehicles.
- Energy savings = (Baseline energy use) – (Measure energy use)
  - Baseline annual energy use (gallons gasoline consumed, conventional vehicle)
    \((9,000) \times (1 \text{ gallon gasoline}/24.7 \text{ miles}) \times (0.116 \text{ MMBtu/gallon gasoline}) = 42.3 \text{ MMBtu}\)
  - Measure annual energy use (electricity consumed, AEV)
    \((9,000) \times (1 \text{kWh}/3.33 \text{ miles}) \times (0.003 \text{ MMBtu/kWh}) = 8.1 \text{ MM BTU}\)
  - Energy savings = 42.3 MMBTU - 8.1 MMBTU = 34.2 MM BTU

**Other Savings**

**GHG emissions:** Use of an electric vehicle will displace 2,915 gallons of gasoline over the 8 year lifetime of the measure (see section Measure Lifetime below). Reductions in greenhouse gas emissions will vary widely by region with the source of electricity generation. National average reductions in CO\(_2\) are estimated to be 14.32 tons (28,643 lbs) over the lifetime of the measure.\(^{17}\)

- National average CO\(_2\) emissions per MWh delivered electricity: 1,307 lbs CO\(_2\)\(^{18}\)
- CO\(_2\) emissions per gallon of gasoline: 19.52 lbs\(^{19}\)
- AEV lifetime energy use (MWh) = (9,000 miles) \times (1 kWh/3.33 miles) \times 8 years \times (1 MWh/ 1,000 kWh) = 21.62 MWh
- CO\(_2\) lifetime savings= (Gasoline vehicle emissions avoided) – (All-electric vehicle emissions):
  - Lifetime gasoline vehicle use avoided: (9,000 miles) \times (1 gallon/24.7 miles) \times 8 years = 2,915 gallons
  - Lifetime gasoline vehicle use avoided: (2,915 gallons gasoline) \times (19.52 lbs CO\(_2\)/gallon) – (21.62 MWh) \times (1,307 lbs CO\(_2\)/MWh) = 28,643 lbs CO\(_2\)

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\(^{13}\) EV Project report

\(^{14}\) FHWA 2012

\(^{15}\) Sales-weighted average miles per gallon of model year 2013 vehicles, calculated in University of Michigan Transportation Research Institute Eco-driving Index, 2013: [http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html](http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html). This average includes all light duty vehicles (cars, SUVs, pick-up trucks) and may include a small number of alternative fuel vehicles. This estimate was the best available of model year 2013 vehicle operating efficiency.

\(^{16}\) Average operating efficiency of all-electric vehicles included on the US EPA site [www.fueleconomy.gov](http://www.fueleconomy.gov) as of January 2014.

\(^{17}\) Per gallon estimates of non-CO\(_2\) vehicle emissions are difficult to estimate. CO\(_2\) accounts for 95-99% of vehicle emissions.

\(^{18}\) US EPA, 2013, Clean Energy Calculations and References

\(^{19}\) US EPA, 2011, Greenhouse Gas Emissions from a Typical Passenger Vehicle
**Health Impacts:** Annual savings in health costs are estimated to be $351 per AEV. At a below average rate of use, a conventional vehicle results in $540 annually in associated health costs resulting from tailpipe emissions:

- 
  - (9,000 miles) x ($0.06) per mile = $540
  - Health costs associated with AEV use (2014 national average generation fuel mix) are $189:
  - (9,000 miles) x (1 kWh/3.3 miles x $0.07/kWh) = $189 annually

**Measure Cost:** The incremental cost of an AEV, exclusive of home charging equipment, is $8,639.

We estimate the average upfront cost of an equivalent conventional 2013 vehicle (fully loaded) to be $25,000, in accordance with the methods used in EPRI, 2013\textsuperscript{20}. At this level, the mean incremental difference between a conventional and electric vehicle is $8,639 as of 2013, using the most price recent data available, excluding AEV incentives and residential EVSE costs (see http://www.afdc.energy.gov/vehicles/electric_availability.html for up to date information; further price details are included in Appendix A of this document).

This price differential will change as the number of available electric models increases. Lease deals and current federal and state incentives make EVs considerably more affordable for consumers and in some cases such deals are actually cheaper than the conventional ICE equivalent. However, because this analysis accounts for the full costs and benefits of AEV purchase and ownership, the full vehicle purchase price is used. The cost of a Level 1 (120 volt) residential EVSE is an additional cost of EV purchase and estimated to be $500 – $1,000 with installation.

**Operation and Maintenance Costs:** The deemed lifetime O&M cost of this measure is $2,173 (electricity) + $648 (maintenance) = $2,821. This is an overall lifetime savings in O&M costs over conventional vehicle baseline of $8,780 ($6,908 savings in fuel costs and $1,872 savings in annual maintenance costs).

**Energy costs**

The deemed energy costs average $271 annually, an average incremental savings of $864 annually.

Annual estimates of gasoline prices and kWh were obtained from the Energy Information Administration 2013 Annual Energy Outlook (EIA 2013).\textsuperscript{21} Between 2014 and 2021, estimates of gasoline costs to power 9,000 vehicle miles range from $1,099 to $1,198 in 2011 dollars. These prices can be further modified for specific locations. Electricity prices range from $267 annually to $274, an average difference of $864 annually in energy costs for vehicle operation and a difference of $6,908 over the lifetime of the measure.

**TABLE 5. ESTIMATED COST TO POWER 9,000 VEHICLE MILES OF TRAVEL**

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>$1,116</td>
<td>$267</td>
</tr>
<tr>
<td>2015</td>
<td>$1,099</td>
<td>$268</td>
</tr>
<tr>
<td>2016</td>
<td>$1,100</td>
<td>$272</td>
</tr>
<tr>
<td>2017</td>
<td>$1,110</td>
<td>$274</td>
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<tr>
<td>2018</td>
<td>$1,129</td>
<td>$274</td>
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<tr>
<td>2019</td>
<td>$1,151</td>
<td>$273</td>
</tr>
<tr>
<td>2020</td>
<td>$1,178</td>
<td>$272</td>
</tr>
<tr>
<td>2021</td>
<td>$1,198</td>
<td>$273</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$9,081</strong></td>
<td><strong>$2,173</strong></td>
</tr>
</tbody>
</table>


\textsuperscript{21} See ‘Calculating Vehicle Energy Cost’ tab in in the accompanying spreadsheet ‘EIA 2013 Energy Price Forecast.xlsx’
Maintenance costs

Maintenance costs were considered for 8 years (warrantied battery lifetime) at 9,000 miles driven annually. Total maintenance costs for 72,000 vehicle miles are estimated to be $648 for an AEV and $2,520 for a conventional gasoline vehicle. Maintenance costs are calculated based on manufacturer suggested vehicle maintenance schedules. Overall maintenance costs of AEVs are expected to be lower than conventional vehicles due to fewer moving and mechanical parts. AEVs experience slower wear of brake pads due to regenerative braking, do not require oil changes, and do not have exhaust systems or clutches.

Coincident Factor: 25%: Based on away-from home charging behavior and observation of charging behavior in areas with and without time of use (TOU) rates, it is assumed that in areas with time of use rates, 75% of charging will occur off-peak. In areas without TOU rates, it is assumed that 60% of charging will occur at home off-peak. In the absence of TOU rates, there is a tendency for AEV drivers to begin charging in the early evening when they return home from work, resulting in a few hours of peak charging. Peak demand generally ends at 10 PM. It is assumed that charging patterns will not vary significantly seasonally, although this assumption can be modified as more data becomes available.

Persistence: Persistence refers to the fraction of gross measure savings obtained over the measure life. For electric vehicles, the persistence is assumed to be 1.00: There are no data available to suggest that energy savings achieved will decline as the battery ages.

Measure Lifetime: 8 years; most AEV batteries are under warranty for 8 years or 100,000 miles. Although the vehicles may change ownership, the presumed lifetime of the measure is 8 years (efficiency benefits will be achieved regardless of who the individual owner is).

Spillover and Free ridership: Rates of spillover and free ridership can be updated as more data on electric vehicle adoption becomes available. Previous research on non-plug-in hybrid vehicles suggests that these vehicles tend to occur in geographic clusters, indicating the potential of a spillover effect. Most likely, the rate of free ridership will depend on the level of incentive provided.

Referenced Documents
- University of Michigan Transportation Research Institute Eco-Driver Index, October 2013: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html
- The EV Project, 2013, PEV Driver Responses to Time-of-Use Rates (TOU) while Charging EV Project Vehicles.

22 EPRI, 2013. Total Cost of Ownership Model for Current Plug-in Electric Vehicles. This document estimates maintenance costs for 100,000 vehicle miles. We discounted these costs by 28% to represent 72,000 miles of vehicle travel.
23 The EV Project, 2013, PEV Driver Responses to Time-of-Use (TOU) Rates While Charging EV Project Vehicles
24 The EV Project Q2 2013 Report
25 See vehicle manufacturer websites.
- Aultman-Hall et al. 2012. Travel Demand and Charging Capacity for Electric Vehicles in Rural States. Transportation Research Record.
COMMERCIAL/PUBLIC LEVEL 2 ELECTRIC VEHICLE SUPPLY EQUIPMENT

**Definition of Efficient Equipment:** Level 2 240 volt Electric Vehicle Supply Equipment at a public or commercial location

**Definition of Baseline:** Level 1 Electric Vehicle Supply Equipment

**Description:** Electric Vehicle Supply Equipment (EVSE) is the infrastructure that is used to charge electric vehicle batteries. At non-residential locations EVSE may simply be a designated outlet in a parking lot or garage, or may include embedded intelligence that allows a fee to be charged for use of the EVSE and communications with a charging network such as ChargePoint. Additional functionality (the ability to charge a fee or communicate with a network) adds substantially to the cost of EVSE installation and often includes a monthly subscription fee. A field study was conducted to examine the relative efficiency of Level 1 and Level 2 EV charging. Details of study methodology are presented in Appendix B. Field observations show that Level 2 240 volt EVSE offers efficiency gains of approximately 5.6% over 120 Volt Level 1 EVSE (see Appendix A). Efficiency gains achieved per unit will be greatest at those EVSE locations that are heavily used, such as downtown areas and retail locations. Data further show that efficiency gains are greatest (approximately 13%) for low energy charge events (those less than 4 kWh). As more data on charging behavior and efficiency becomes available, multiple savings profiles may be created. There is potential to make this measure semi-custom, accounting for variations in efficiency that come with charge duration. Categories by EVSE location (parking lot, grocery store, mall, Park and Ride) can be created with savings estimates based on average length of charge.

**Deemed Annual Energy Savings:** 403 kWh per unit (Savings will vary depending on the amount of charging done at a particular EVSE and with charge durations.) Mean efficiency gains of Level 1 over Level 2 are 5.6% on average, and 13% for charge events when less than 4 kWh is taken up by the vehicle battery. Charging efficiency is defined as:

\[
\text{(total energy taken up by the vehicle battery)} \div \text{(total energy drawn from the grid)} \times 100
\]

Heavily used public EVSE currently report 600 kWh of monthly use (7,200 kWh annually), although this value is expected to grow with adoption of electric vehicles. Although charge events less than 4kWh (approximately one hour of charging at Level 2) presumably are not uncommon at public EVSE, until more data is available, deemed savings are based on the overall efficiency gain. Future calculations may use a weighted average to determine savings.

\[ (7,200 \text{ kWh}) \times (0.056) = 403 \text{ kWh} \]

**Operating Hours:** The number of hours each unit is in operation will vary with location and vehicle charging capacity. On average, 600 kWh of energy used at a given EVSE will equate to approximately 120 hours of use. The rate at which vehicles can charge is limited by the vehicle’s internal charger, which generally range from 3.3 to 6.6 kW capacity (Newer models of all-electric Vehicles tend to have a 6.6 kW charger while Plug-in Hybrid Electric Vehicles often have a 3.3 kW charger). Assuming an average charger capacity of 5 kW, operating hours can be estimated by:

\[ (600 \text{ kWh used at EVSE per month}) \div (5 \text{ kW average vehicle internal charger capacity})= 120 \text{ operating hours at EVSE} \]
**Other Savings:** Like energy savings GHG emission reductions will vary with the amount of EVSE usage but an overall reduction of 5.6% is expected. Over the lifetime of the measure, avoiding 432 kWh annually in electricity would amount to 5,646 lbs CO₂ avoided (2.8 tons) and $302 in health impacts avoided.

- National average CO₂ emissions per MWh delivered electricity: 1,307 lbs CO₂
- Lifetime avoided emissions through improved efficiency = (403 kWh annual energy savings per unit) x (1 MWh/1,000 kWh) x 1,307 lbs CO₂ x 10 years = 5,267 lbs CO₂ (2.6 tons)
- Health impacts of avoided electricity=(403kWh annual energy savings per unit) x ($0.07/kWh) x 10 years = $282

**Measure Cost:** The incremental measure cost of a Level 2 EVSE will vary with site characteristics and system functionality (i.e., capability to charge users a fee, to interact with advanced metering infrastructure, participate in demand response programs). These costs are changing quickly and should be tailored to the geography of interest. Estimated total cost of baseline equipment (commercial/public Level 1 EVSE) and installation ranges from $230 to $1,350, although depending on the requirements of the site and trenching and signage needs, the cost could be more. In locations where wiring already exists, the cost could be close to zero. Measure costs (commercial/public Level 2 EVSE), including installation, are estimated to be $2,600-$21,000, although again, this cost will vary by site and with system functionality.

**Maintenance Costs:** Maintenance costs are not expected to differ between Level 1 and Level 2 EVSE.

**Coincident Factor:** 75%: Most use of commercial EVSE occurs during business hours 9-5, and will thus add to peak load (although definitions of ‘peak’ can vary by utility territory). Region specific data of charging behavior at public EVSE may be available through The EV Project (www.theevproject.com).

**Persistence:** 1.00: There is no data to suggest that efficiency gains will decline over the lifetime of the measure.

**Measure Lifetime:** 10 years (length of unit warranty; see individual EVSE manufacturer websites)

**Spillover and Free Ridership:** N/A

**Referenced Documents**
- Appendix B
- The EV Project. 2013. PEV Driver Responses to Time-of-Use (TOU) Rates While Charging EV Project Vehicles.

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27 US EPA, 2013, Clean Energy Calculations and References
RESIDENTIAL LEVEL 2 ELECTRIC VEHICLE SUPPLY EQUIPMENT

Definition of Efficient Equipment: Residential Level 2 240 Electric Vehicle Supply Equipment

Definition of Baseline: Residential Level 1 Electric Vehicle Supply Equipment

Description: Electric Vehicle Supply Equipment (EVSE) is the infrastructure used to charge electric vehicle batteries. Residential EVSE is nearly always either Level 1 (120 volt) or Level 2 (240 volt EVSE) and may be as simple as an outlet in a driveway or garage with a dedicated electric line. Access to EV charging in multi-family residences can be a challenge. In order for EV ownership to be practical for residents in multifamily dwellings, dedicated grounded outlets in parking or garage space must be available to EV-owning tenants. A field study was conducted to examine the relative efficiency of Level 1 and Level 2 EV charging. Details of study methodology are presented in Appendix B. Field observations show that Level 2 240 volt EVSE offers efficiency gains of approximately 5.6% over 120 volt Level 1 EVSE. Savings will vary with use and thus type of EV. Savings will be greatest for all-electric vehicles (AEVs), which have larger batteries and longer ranges than plug-in hybrid electric vehicles (PHEVs). PHEVs use less electric energy than all-electric vehicles so fewer savings will be achieved through a switch from residential Level 1 to Level 2 EVSE.

Deemed Annual Energy Savings

- AEV: 113 kWh per unit
- PHEV-12: 33 kWh per unit
- PHEV-21: 78 kWh per unit
- PHEV-35: 93 kWh per unit
- (Savings will vary depending on the amount of charging done at a particular EVSE and with charge durations.)

Assumptions and Supporting Calculations

- Annual electric vehicle miles traveled: 9,000 (slightly lower than the national average of 10,650 miles)
- Average efficiency of AEVs available, model year 2013: 3.33 miles per kWh

<table>
<thead>
<tr>
<th>Electric Range</th>
<th>Miles per kWh (avg.)</th>
<th>% of miles in electric mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>3.4</td>
<td>30 (estimate, no data available)</td>
</tr>
<tr>
<td>21</td>
<td>2.9</td>
<td>60</td>
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<td>38</td>
<td>2.6</td>
<td>64</td>
</tr>
</tbody>
</table>

Deemed Annual Savings by Vehicle Type

Annual energy savings were calculated as (annual miles driven) x (% miles powered by electricity) x (% performed at home)/ (vehicle operating efficiency) x (efficiency gain of Level 2 EVSE over Level 1 EVSE)

Mean efficiency gains of Level 1 over Level 2 are 5.6% on average. Charging efficiency is defined as: (total energy taken up by the vehicle battery) ÷ (total energy drawn from the grid) x 100

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28 EV Project report
29 FHWA 2012
32 Estimate from Ford Motor Company based on Fusion and C-Max owners
33 Estimate from Chevrolet based on Volt owners
**Supporting Calculations**

- **AEV**: (9,000 miles) x (100% miles powered by electricity) x (75% at home charging) / (3.33 miles per kWh) x (5.6% efficiency gain) = 113 kWh
- **PHEV-12**: (9,000 miles) x (30% miles powered by electricity) x (75% at home charging) / (3.4 miles per kWh) x (5.6% efficiency gain) = 33 kWh
- **PHEV-21**: (9,000 miles) x (60% miles powered by electricity) x (75% at home charging) / (2.9 miles per kWh) x (5.6% efficiency gain) = 78 kWh
- **PHEV-35**: (9,000 miles) x (64% miles powered by electricity) x (75% at home charging) / (2.6 miles per kWh) x (5.6% efficiency gain) = 93 kWh

**Other Savings**: Like energy savings GHG emission reductions will vary with the level of EVSE use but an overall reduction of 5.6% is expected. Over the lifetime of the measure, avoiding between 33 kWh and 113 kWh annually would amount to between 431 and 1,477 lbs CO₂ avoided.

National average CO₂ emissions per MWh delivered electricity: 1,307 lbs CO₂

Lifetime avoided emissions through improved efficiency =

- **EV**: (113 kWh) x (1 MWh/1,000 kWh) x 1,307 lbs CO₂ x 10 years = 1,477 lbs CO₂ (0.7 tons)
- **PHEV-12**: (33 kWh) x (1 MWh/1,000 kWh) x 1,307 lbs CO₂ x 10 years = 431 lbs CO₂ (0.2 tons)
- **PHEV-21**: (78kWh) x (1 MWh/1,000 kWh) x 1,307 lbs CO₂ x 10 years = 1,019 lbs CO₂ (0.5 tons)
- **PHEV-35**: (93kWh) x (1 MWh/1,000 kWh) x 1,307 lbs CO₂ x 10 years = 1,215 lbs CO₂ (0.6 tons)

Health impacts of avoided electricity over the measure lifetime are nominal (< $100).

**Measure Cost**: The incremental measure cost of a base unit Level 2 EVSE is $900. A base Level 2 EVSE is estimated to cost $1,500 to $1,800, including installation. Installation costs will vary, depending on site characteristics. Baseline equipment costs, including installation are estimated to be $500-$1,000.

**Maintenance Costs**: Maintenance costs are not expected to differ between Level 1 and Level 2 EVSE.

**Coincident Factor**: 25%: Based on away-from home charging behavior and observation of charging behavior in areas with and without TOU rates, it is assumed that in areas with time of use rates, 75% of charging will occur off peak. In areas without TOU rates, it is assumed that 60% of charging will occur at home off peak. In the absence of TOU rates, there is a tendency for EV drivers to begin charging in the early evening when they return home from work, resulting in a few hours of peak charging (peak demand generally ends at 10 PM). It is assumed that charging patterns will not vary significantly seasonally, although this assumption can be modified as more data becomes available.

**Persistence**: 1.00: There is no data to suggest that efficiency gains will decline over the lifetime of the measure.

**Measure Lifetime**: 10 years (length of unit warranty; see manufacturer websites)

**Spillover and Free ridership**: N/A

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34 US EPA, 2013, Clean Energy Calculations and References
35 The EV Project, 2013, PEV Driver Responses to Time-of-Use (TOU) Rates While Charging EV Project Vehicles
36 The EV Project Q2 2013 Report
Referenced Documents

- Appendix B
- The EV Project. 2013. PEV Driver Responses to Time-of-Use (TOU) Rates While Charging EV Project Vehicles.
Conclusion

This document presents the general values and calculations needed to assess three transportation efficiency measures. Many of the values presented in this document are national averages that should be tailored to specific locations as needed (individual states, utility service areas, metropolitan areas, counties, etc.). In addition, the methodology presented can easily be extended to assess the energy and non-energy benefits of other transportation efficiency measures, including bicycling and walking infrastructure, ultra efficient conventional vehicles, and natural gas vehicles. Transportation efficiency and a comprehensive means of measuring such efficiency have relevance for all stakeholders involved in energy and transportation planning.
References

Aultman-Hall et al. 2012. Travel Demand and Charging Capacity for Electric Vehicles in Rural States. Transportation Research Record.


California Carbon Dashboard: http://calcarbondash.org/.


The EV Project. 2013. PEV Driver Responses to Time-of-Use Rates (TOU) while Charging EV Project Vehicles.


Oak Ridge National Laboratory. 2013. Transportation Energy Data Book, Table 2-12.


University of Michigan Transportation Research Institute Eco-Driving Index, October 2013: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html


Appendix A

Prices of 2013 and 2014 All-Electric Vehicles

Prices of available 2013 and 2014 all-electric vehicles as of December 2013. The base model AEV price is used in this analysis. As noted in EPRI (2013), base model AEVs tend to come with standard features not available in their base model conventional equivalent. In the EPRI report, base model AEVs and plug-in hybrid electric vehicles are compared to fully loaded conventional vehicles. For updated price information, see manufacturer websites or http://www.afdc.energy.gov/vehicles/electric_availability.html.

TABLE 7. PRICES OF 2013 AND 2014 ALL-ELECTRIC VEHICLES

<table>
<thead>
<tr>
<th>Electric Model</th>
<th>MSRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 Ford Focus Electric</td>
<td>$35,995</td>
</tr>
<tr>
<td>2013 Nissan Leaf</td>
<td>$28,800</td>
</tr>
<tr>
<td>2014 Chevrolet Spark Electric</td>
<td>$34,185</td>
</tr>
<tr>
<td>2014 Honda Fit EV</td>
<td>$37,415</td>
</tr>
<tr>
<td>2013 Fiat 500e</td>
<td>$31,800</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>$33,639</strong></td>
</tr>
</tbody>
</table>
Appendix B

ESTIMATING EFFICIENCY OF LEVEL 1 AND 2 ELECTRIC VEHICLE SUPPLY EQUIPMENT

A field study was conducted to estimate the relative efficiencies of Level 1 and Level 2 Electric Vehicle Supply Equipment (EVSE). This study built upon previous research of the Chevrolet Volt which found Level 2 EV charging to be 2.7% more efficient than Level 1 charging, on average, and as much as 12.8% more efficient for shorter charge events (those that draw less than 2kWh from the grid; Sears et al. 2014).

METHODOLOGY

Logging devices were installed in 2 Chevrolet Volts and 2 Nissan Leafs to measure charging efficiency of each vehicle charging event. Although our sample size was very limited, the study is intended to provide preliminary data and results on this topic. All vehicles were located and charged in Vermont and data was collected between June and November 2013. The Volts were outfitted with the F-5 logging device from the company FleetCarma, which plugged into the vehicle dash and collected data on the amount of energy received from the EVSE and the amount taken up by the vehicle battery.

There was no similar device available for the Nissan Leaf (one that directly measures energy uptake by both the vehicle charger and the vehicle battery) but we wanted to ensure that at least two EV models were included in our study. To estimate charging efficiency of the Nissan Leaf, a vehicle logging device was used in combination with a meter on the EVSE unit. One device, the WattsLeft™ monitor was plugged into the vehicle and measured the amount of energy taken up by the battery at each charging event. Another device, the Watts Up meter, was attached to the EVSE unit and measured the amount of energy that was taken from the grid during each charging event.

For both logging devices, the efficiency of each charge event was calculated as:

\[
\frac{\text{total energy taken up by the vehicle battery}}{\text{total energy drawn from the grid}} \times 100
\]

Usable data was collected from a total of 115 charge events, 64 Level 1 and 51 Level 2. Of these 115 charge events, 75 were Chevrolet Volts and 39 were Nissan Leafs. We found mean charge efficiency for all charge events to be 85.7% ± 0.09 SD.

Because previous research (Sears et al. 2014) indicated that charging efficiency of the Chevrolet Volt was affected by ambient temperature and charge duration, we also examined the effects of these factors on charging efficiency. Hourly temperature data for each charge event was obtained from the Cornell Northeast Regional Climate Center. We observed that the efficiency of low energy charge events (those in which the battery took up less than 4 kWh), was generally lower, especially for Level 1 charging. Level 1 ‘low charge events’ exhibited an average charge efficiency of 74.2% and Level 2 low charge events exhibited a mean efficiency of 87.2%. In addition, we observed that high ambient temperatures (> 70°F) reduced charging efficiency of Level 1 charges to 81.4%, but there was no similar effect observed for cold temperatures (< 50°F). Ambient temperature did not appear to affect the efficiency of Level 2 charge events within the temperature ranges examined. There may be effects on charging efficiency at lower temperatures (e.g., < 40°F or < 30°F) but we did not have enough observations for both Level 1 and Level 2 charging events at these temperatures to assess these effects. The table below summarizes the study results.
TABLE 8. ESTIMATING EFFICIENCY OF LEVEL 1 AND 2 ELECTRIC VEHICLE SUPPLY EQUIPMENT

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean charge efficiency (%) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All charge events</td>
<td>114</td>
<td>85.7 ± 0.09</td>
</tr>
<tr>
<td>Level 1</td>
<td>63</td>
<td>83.8 ± 0.08</td>
</tr>
<tr>
<td>Level 2</td>
<td>51</td>
<td>89.4 ± 0.05</td>
</tr>
<tr>
<td>Level 1 charge events &lt; 4kWh</td>
<td>11</td>
<td>74.2 ± 0.12</td>
</tr>
<tr>
<td>Level 2 charge events &lt; 4kWh</td>
<td>13</td>
<td>87.2 ± 0.06</td>
</tr>
<tr>
<td>Level 1 charge events &lt; 50°F</td>
<td>32</td>
<td>83.0 ± 0.09</td>
</tr>
<tr>
<td>Level 1 charge events &gt; 70°F</td>
<td>9</td>
<td>81.4 ± 0.09</td>
</tr>
<tr>
<td>Level 2 charge events &lt; 50°F</td>
<td>23</td>
<td>90.6 ± 0.04</td>
</tr>
<tr>
<td>Level 2 charge events &gt; 70°F</td>
<td>10</td>
<td>89.9 ± 0.04</td>
</tr>
</tbody>
</table>

The previous research cited above reported that temperatures below 53°F and above 70°F reduced charging efficiency for charge events that drew less than 2kWh from the grid. Due to limited sample size, we were not able to examine combined effects of temperature and charge duration. Further data collection can clarify the effects of ambient temperature on Level 1 and 2 EV charging efficiency. Energy savings may vary seasonally and may be greater in hot or cold climates.
Appendix C

CUSTOMIZED TRANSPORTATION TRM FOR THE STATE OF UTAH

The following analysis adapts the Transportation TRM model for transportation efficiency in Utah, developing measures tailored to Utah’s travel patterns and electric generating mix. Specifically, it compares two plug-in electric vehicle models (EVs) against a baseline conventional internal combustion vehicle. Our results reveal that over the 8 year lifetime of the vehicle:

- Use of an EV in place of a gasoline vehicle saves $1,185-$1,296 in health costs through reduced tailpipe emissions.
- EVs offer greater energy security costs than gasoline, valued at $704-$1,224.
- Overall, all electric vehicles provide a total savings of over $4,000.

Clearly, there are public health and environmental health benefits associated with the adoption of EVs in place of conventional vehicles. Further, this document demonstrates that the TRM model provides a meaningful way to compare transportation efficiency measures.

CONTEXT

Although TRMs have traditionally been used in the regulated realm, they can also inform energy policy as it applies to transportation energy. A Transportation TRM can guide policy and program development to create financing, incentives and/or state and local fleet conversion efforts. Importantly, many state energy offices are not limited in the same way that utilities and public utility commissions may be regarding fuel switching; rather, for State Energy Offices such as the Utah Office of Energy Development, a switch to a more efficient fuel or mode may simply represent optimal management of a state’s transportation energy portfolio. In Utah, transportation comprises 32% of the state’s primary energy consumption, the largest of any sector, highlighting the opportunity for efficiency improvements within this sector. Additionally, in the 2014 American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, Utah was awarded only 1.5 out of 9 possible points for transportation policies, fewer than both Arizona and Colorado.

This document provides assumptions, default values, and equations used to calculate the energy and cost savings of two transportation efficiency measures using the Societal Cost Test (SCT). The measures included in this manual will not necessarily pass the cost-effectiveness screening process in all locations. The goal of this document is to provide a framework and some basic data for such screening. The computations utilize Utah-specific data when available.

PREDICTING THE IMPACT OF EVS ON ELECTRICITY DEMAND IN UTAH

For the purposes of this analysis, the term electric vehicle (EV) refers to all plug-in vehicles- both all-electric and plug-in hybrid. Predicting how EVs will impact electricity demand involves consideration of not only of how many EVs will be charging in the state (the amount of new demand), but what time of day charging will occur (during peak vs. off-peak hours), and how that demand will be spatially distributed. Nationally, over 350,000 EVs have been purchased. As of May 2015, there were over 1,200 EVs registered in Utah, as illustrated in Figure 1. The additional

37 The State of My State’s EVs: http://www.casteyanqui.com/ev/utah_sales/index.html
demand of one all-electric vehicle load is estimated to be 2,700 kWh annually, approximately 30% of average household load in Utah.  

**FIGURE 3. CUMULATIVE PLUG-IN VEHICLE SALES IN UTAH**

![Cumulative Plug-In Vehicle Sales in Utah by Quarter](image)

**Number of EVs on the Road:** According to research by the Center for Automotive Research, or CAR (2011), Utah is not predicted to be among the top states for per capita EV adoption in coming years, although this could certainly change with the availability of government incentives or other programs to promote EVs. CAR predicted future EV penetration based on current rates of non-plug-in hybrid registrations. Utah ranked 33rd in the nation for hybrid registrations and is predicted to have 3,000 EVs on the road by 2015. Presumably, this new electric fleet will be comprised of both all electric (AEV) and plug-in hybrid electric vehicles (PHEVs). Nationally, approximately half of 2014 plug-in vehicle sales were all electric vehicles, and the rest PHEVs (Inside EVs 2014). PHEV electricity use will vary depending on individual travel patterns and vehicle battery size. We estimate that on average, each PHEV will require approximately 1,800 kWh annually and each AEV 2,700 kWh.

CAR projections of EV sales suggest that total EV charging will result in an additional 6,750 MWh of demand, statewide. Projections of EV penetration are also available through the Energy Information Administration (EIA). EV estimates based on EIA projections are considerably lower than those from CAR. Between 2007 and 2009, 0.6% of all hybrid vehicle sales occurred in Utah. Applying this percentage to the total number of EVs predicted in the United States for each of the next eight years (Table 3), we calculate approximately 2,500 EVs in Utah by 2023. It is worth noting that the cumulative number of EV sales in the US is well over 250,000, considerably more than the 70,256 predicted nationwide for 2014 by the EIA (Electric Drive Transportation Association 2014).

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38 Average household electricity use was 8,896 kWh in Utah in 2010, SWEEP 2014: [http://swenergy.org/publications/state-fact-sheets](http://swenergy.org/publications/state-fact-sheets)

### TABLE 9. UTAH PLUG-IN VEHICLE SALES PROJECTIONS

<table>
<thead>
<tr>
<th>Year</th>
<th>Cumulative US EV sales predictions</th>
<th>Cumulative Utah EV sales predictions (EIA)</th>
<th>Cumulative Utah EV sales predictions (CAR)</th>
<th>Additional MWh demand in Utah$^{40}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>70,256</td>
<td>422</td>
<td>2,112</td>
<td>950</td>
</tr>
<tr>
<td>2015</td>
<td>130,255</td>
<td>782</td>
<td>3,000</td>
<td>1,760</td>
</tr>
<tr>
<td>2016</td>
<td>151,064</td>
<td>906</td>
<td></td>
<td>2,038</td>
</tr>
<tr>
<td>2017</td>
<td>203,726</td>
<td>1,222</td>
<td></td>
<td>2,749</td>
</tr>
<tr>
<td>2018</td>
<td>273,714</td>
<td>1,642</td>
<td></td>
<td>3,695</td>
</tr>
<tr>
<td>2019</td>
<td>283,648</td>
<td>1,702</td>
<td></td>
<td>3,829</td>
</tr>
<tr>
<td>2020</td>
<td>308,944</td>
<td>1,854</td>
<td></td>
<td>4,171</td>
</tr>
<tr>
<td>2021</td>
<td>362,844</td>
<td>2,177</td>
<td></td>
<td>4,898</td>
</tr>
<tr>
<td>2022</td>
<td>395,529</td>
<td>2,373</td>
<td></td>
<td>5,339</td>
</tr>
<tr>
<td>2023</td>
<td>419,423</td>
<td>2,517</td>
<td></td>
<td>5,663</td>
</tr>
</tbody>
</table>

*Sources: Energy Information Administration and the Center for Automotive Research*

**Timing of EV Charging:** The bulk of EV charging takes place at home charging stations and there is potential for some of this charging to occur during peak hours if drivers plug-in immediately upon returning home at the end of the day (between 4 and 7 PM). The most complete data on charging behavior is available through the EV Project, a DOE-funded initiative that has been tracking travel and charging behavior of thousands of EVs in nine states since 2011. Data from this project has shown that in areas with time of use (TOU) rates, the majority of EV charging occurs during off-peak hours. This was not the case in areas without TOU rates, where demand generally peaked in the early evening when EV owners returned home from work (Schey et al. 2012, EV Project 2013). Figure 2 shows how TOU rates in San Diego and San Francisco encourage nighttime charging, in contrast to Los Angeles and Washington State, which lack TOU rates.

TOU rates are one way that utilities can encourage EV charging at times when demand on the grid is low and effectively fill valleys in system demand (Glazner 2012, Kintner-Meyer et al. 2007, Parks et al. 2007). Analyses of the projected impacts of EV charging on regional utilities across the United States have concluded that by having EVs charging during off-peak evening hours, utilities can increase profitability and/or potentially lower electricity rates for customers (Galus et al. 2012, Scott et al. 2007).

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$^{40}$Assumes that 50% of EV purchases will be all electric vehicles with an annual usage of 2,700 kWh annually, and 50% will be PHEVs with an average electric usage of 1,800 kWh annually.
Location of EVs: There is evidence to suggest that EV penetration may be clustered, as hybrid vehicle penetration has been; those people who live near a hybrid vehicle are more likely to be hybrid owners themselves (Aultman-Hall et al. 2012). There is some question as to how well the current electricity distribution network will be able to accommodate the additional load resulting from EV charging and potential clustering of that load (Shao et al. 2009, Hilshey et al. 2013). Distribution transformers generally serve four to ten households. An electric vehicle uses about one-third of one household’s annual energy; thus, even a small degree of clustering might be problematic (EIA 2011, Sullivan 2009). EV deployment can be tracked through collaboration with the Utah DMV (generally EVs can be identified in the database with their Vehicle Identification Number, or VIN). In addition, the State Energy Office, in collaboration with utilities, may consider encouraging customers to notify their utility when an EV is purchased or a charging station installed. Such an effort would aid in efforts to track EV and EVSE deployment and avoid any issues that may arise from clustering of EV charging in the future.

Additional Demand from PHEVs: The electricity demand of plug-in hybrid electric vehicles (PHEVs) (such as the Chevy Volt and Ford CMax Energi) will depend on the vehicle battery size and range, as will associated costs and benefits. Expected PHEV annual electricity usage is estimated to be between 794 kWh and 2,215 kWh per vehicle, but could be considerably higher if a greater percentage of miles are powered by electricity (Table 4).
TABLE 10. PHEV ELECTRIC RANGE AND OPERATING EFFICIENCY

<table>
<thead>
<tr>
<th>Electric Range</th>
<th>Miles per gallon (avg.)</th>
<th>Miles per kWh (avg.)</th>
<th>Percent of miles in electric mode</th>
<th>Expected annual kWh usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-13</td>
<td>48</td>
<td>3.4</td>
<td>30 (estimate, no data available)</td>
<td>794</td>
</tr>
<tr>
<td>21</td>
<td>43</td>
<td>2.9</td>
<td>60(^{42})</td>
<td>1,862</td>
</tr>
<tr>
<td>38</td>
<td>37</td>
<td>2.6</td>
<td>64(^{43})</td>
<td>2,215</td>
</tr>
</tbody>
</table>

EVs have the potential to introduce a substantial new source of electricity demand to Utah’s grid in the next decade, thus it is crucial that EV planning include consideration of the geographic distribution of EVs and charging stations in the state and utilize techniques to ensure that the bulk of charging occurs during off-peak hours. Ways of mitigating EV demand include TOU rates and smart charging algorithms (these would require advanced metering infrastructure in most cases). There is already considerable data suggesting that travel patterns between EV drivers and drivers of conventional vehicles are roughly similar (EV drivers logged 9,000 annual miles on average, according to the The EV Project, similar to the state average in Utah). EV charging that occurs at networked charging stations (those that are linked into a system such as Blink or EV2Go or ChargePoint) can be tracked by charging station owners. Thus, the additional demand posed by each EV can be predicted with some accuracy, but the timing and location of that demand is also important.

**Grid Services:** There is potential for EVs to serve as a resource to the grid in the future, reducing the impact of additional demand and facilitating overall electric system efficiency. Broadly, EVs can be used in demand response programs to reduce peak demand or serve as distributed energy resources, storing excess energy during times of low demand and feeding it back to the grid during times of high demand, when electricity prices tend to be highest. EVs also have potential to facilitate increased integration of renewable sources of energy into the grid. Renewable sources, such as solar and wind power, are intermittent and can only be integrated into the generation mix to a limited extent without energy storage capacity. In the future, EVs may be able to serve as distributed energy storage devices, storing and dispatching energy when needed, as described above. At present, two-way exchange of energy voids most EV battery warranties, but vehicle-to-grid systems are an active area of research at the University of Delaware and Department of Defense (Fort Carson Army Post in Colorado Springs). In addition, demonstration residential vehicle-to-building systems are underway in Japan using Nissan Leafs.

Although many IRPs included mention of EVs, few performed any additional modeling efforts to incorporate them into their demand forecasts. At most, EVs were predicted to add one to five percent of additional load. However, although some utilities, such as San Diego Gas and Electric, do not explicitly mention EVs in their IRPs, their company websites include extensive resources for customers regarding EVs. This suggests that although EVs have not necessarily been incorporated into the IRP process, they are on utilities’ radar. Few utilities have begun to consider demand response and other EV grid services in their plans.

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\(^{42}\) Estimate from Ford Motor Company based on Fusion and C-Max owners  
\(^{43}\) Estimate from Chevrolet based on Volt owners
A robust prediction of how EVs will impact demand for electricity requires consideration of how many EVs will be charging, when they will be charging and where they will be charging. EVs will most likely present substantial new demand to the Utah electric grid over the next decade. However, they also provide considerable opportunity to improve overall system efficiency by filling in valleys in demand through off-peak charging, as well as potential to participate in demand response programs, further reducing peak demand.

**UTAH AFV INCENTIVE PROGRAMS**
Utah has provided a variety of alternative fuel incentives in recent years. There are currently over 1,200 EVs registered in the state. A recent report by the International Council on Clean Transportation concludes that state incentives (purchase incentives, tax credits, HOV access, etc.) are significantly correlated with EV sales: states with the most generous incentive programs also tend to have above-average rates of EV adoption (ICCT 2014).

**Before 2009:** The State of Utah offered a $2,500 nonrefundable tax credit for propane, natural gas, and electricity conversions. There was an additional tax credit of fifty percent of the incremental cost ($3,000 cap) for the purchase of new Original Equipment Manufacturer (OEM) vehicles that were fueled by propane, natural gas, or electricity. The incremental cost is the difference between the cost of a new clean fuel vehicle and the cost of the same model without the clean fuel system.

**2009-2013:** The State of Utah continued to offer the $2,500 nonrefundable tax credit for propane, natural gas, and electricity conversions. Additionally, a tax credit for new, non-natural gas vehicles that met certain fuel economy and air quality standards was $750 for vehicles bought in 2009-2010, and $605 for vehicles bought after January, 1, 2011. OEM natural gas purchases were eligible for a tax credit of thirty-five percent of the vehicles purchase price, up to $2,500.

**2014-Present:** The state provides an income tax credit of 35% of the vehicle purchase price, up to $2,500, for an original equipment manufacturer compressed natural gas (CNG) vehicle registered in Utah. It also provides an income tax credit of 50% of the cost to convert a vehicle to run on propane, natural gas, or electricity, up to $2,500. Other new clean fuel vehicles that meet air quality and fuel economy standards may be eligible for a credit of $605, including certain electric and hybrid electric vehicles (Alternative Fuels Data Center, 2014).

**Jan. 1, 2015:** Beginning January 1, 2015, vehicles registered in Utah that are powered by propane, natural gas, and electricity are eligible for an income tax credit of 35% of the vehicle purchase price, up to $1,500. Plug-in hybrid electric vehicles will be eligible for a tax credit of $1,000. The tax credit expires December 31, 2015.

**TABLE 11: ELECTRIC VEHICLE TAX INCENTIVES IN UTAH SINCE 2008**

<table>
<thead>
<tr>
<th>Tax Year</th>
<th>Type of Credit</th>
<th>Technology</th>
<th>Number of Credits</th>
<th>Sum of Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Conversion</td>
<td>Electric</td>
<td>5</td>
<td>$12,500</td>
</tr>
<tr>
<td>2009</td>
<td>Conversion</td>
<td>Electric</td>
<td>2</td>
<td>$4,610</td>
</tr>
<tr>
<td>2010</td>
<td>Conversion</td>
<td>Electric</td>
<td>5</td>
<td>$11,700</td>
</tr>
<tr>
<td>2011</td>
<td>Conversion</td>
<td>Electric</td>
<td>1</td>
<td>$2,500</td>
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<td>2011</td>
<td>Air Quality Standard</td>
<td>Electric</td>
<td>3</td>
<td>$1,815</td>
</tr>
<tr>
<td>Tax Year</td>
<td>Type of Credit</td>
<td>Technology</td>
<td>Number of Credits</td>
<td>Sum of Credits</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------</td>
<td>------------------</td>
<td>-------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>2011</td>
<td>Air Quality Standard</td>
<td>Plug-in Hybrid</td>
<td>13</td>
<td>$7,865</td>
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<td>2012</td>
<td>Conversion</td>
<td>Electric</td>
<td>3</td>
<td>$7,500</td>
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<tr>
<td>2012</td>
<td>Air Quality Standard</td>
<td>Electric</td>
<td>6</td>
<td>$3,630</td>
</tr>
<tr>
<td>2012</td>
<td>Air Quality Standard</td>
<td>Plug-in Hybrid</td>
<td>19</td>
<td>$11,495</td>
</tr>
<tr>
<td>2013</td>
<td>Conversion</td>
<td>Electric</td>
<td>1</td>
<td>$2,500</td>
</tr>
<tr>
<td>2013</td>
<td>Air Quality Standard</td>
<td>Electric</td>
<td>16</td>
<td>$9,680</td>
</tr>
<tr>
<td>2013</td>
<td>Air Quality Standard</td>
<td>Plug-in Hybrid</td>
<td>36</td>
<td>$21,780</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>110</strong></td>
<td><strong>$97,575</strong></td>
</tr>
</tbody>
</table>

**TECHNICAL REFERENCE MANUAL**

**Definition of Efficient Equipment**

Efficient equipment includes:

- All electric vehicle (AEV)
- Plug-in hybrid electric vehicle (PHEV)\(^4\)

**Definition of Baseline:** Gasoline-powered internal combustion engine vehicle

**TABLE 12. SUMMARY OF LIFETIME SAVINGS RELATIVE TO BASELINE**

<table>
<thead>
<tr>
<th></th>
<th>AEV</th>
<th>PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy savings (MMBtu)</td>
<td>274</td>
<td>216</td>
</tr>
<tr>
<td>GHG savings (tons CO(_2) eq)</td>
<td>14.2</td>
<td>8.6</td>
</tr>
<tr>
<td>Monetized savings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG savings at $100/ton CO(_2) eq</td>
<td>$1,420</td>
<td>$806</td>
</tr>
<tr>
<td>Avoided health impacts</td>
<td>$1,185</td>
<td>$1,296</td>
</tr>
<tr>
<td>Avoided energy security costs</td>
<td>$1,224</td>
<td>$704</td>
</tr>
<tr>
<td>Operation and maintenance savings</td>
<td>$5,900</td>
<td>$2,273</td>
</tr>
<tr>
<td>Incremental measure cost</td>
<td>$5,000</td>
<td>$5,500</td>
</tr>
<tr>
<td>Total monetized savings relative to conventional vehicle</td>
<td>$4,729</td>
<td>$79</td>
</tr>
</tbody>
</table>

\(^4\) The electric range of PHEV models ranges from 11-35. For simplicity, we examine a PHEV with a range of 21

39
Assumptions and supporting calculations

- Annual vehicle miles traveled: 9,000\(^{45}\)
- Average fuel efficiency of new conventional vehicles sold, model year 2013: 24.7 miles per gallon\(^{46}\)
- Average efficiency of AEVs available, model year 2013: 3.33 miles per kWh (901 Btu per mile)\(^{47}\)
- Average efficiency of PHEV: 2.9 miles per kWh electric mode, 43 miles per gallon gasoline mode
- Travel patterns are assumed to be the same for all vehicles.

\[ \text{Energy savings} = (\text{Baseline energy use}) - (\text{Measure energy use}) \]

- Baseline annual energy use (gallons gasoline consumed)
  \[ (9,000 \text{ miles}) \times (1 \text{ gallon gasoline}/24.7 \text{ miles}) \times (0.116 \text{ MMBtu/gallon gasoline}) = 42.3 \text{ MMBtu} \]
- AEV energy use (electricity consumed)
  \[ (9,000 \text{ miles}) \times (1kWh/3.33 \text{ miles}) \times (0.003 \text{ MMBtu/kWh}) = 8.1 \text{ MMBTU} \]
- PHEV energy use (electricity and gasoline consumed)
  \[ (9,000 \text{ miles}) \times (1kWh/2.9 \text{ miles}) \times (60\% \text{ miles powered by electricity}) \times (0.003 \text{ MMBtu/kWh}) + (9,000 \text{ miles}) \times (1 \text{ gallon}/43 \text{ miles}) \times (40\% \text{ miles powered by gasoline}) \times (0.116 \text{ MMBtu/gallon gasoline}) = 15.2 \text{ MMBtu} \]

**GHG Impacts**

Annually, each AEV is expected to offset 3,553 lbs of GHG annually and each PHEV 2,648 lbs of GHG. Over the 8 year life span of the vehicle, savings are estimated to be 14.2 tons GHG for AEVs and 8.6 tons for PHEVs.

<table>
<thead>
<tr>
<th>Operating efficiency</th>
<th>Rate of GHG emissions</th>
<th>Annual GHG emissions at 9,000 miles (lbs CO(_2) eq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional vehicle</td>
<td>24.7 mpg</td>
<td>23.4 lbs/gallon gasoline(^{48})</td>
</tr>
<tr>
<td>All electric vehicle</td>
<td>1 kWh/3.33 miles</td>
<td>1,840 lbs/MWh(^{49})</td>
</tr>
<tr>
<td>Plug-in hybrid electric</td>
<td>1 kWh/2.9 miles; 43 mpg(^{50})</td>
<td>1,840 lbs/MWh; 23.4 lbs/gallon gasoline</td>
</tr>
</tbody>
</table>

**Health Impacts**

Annually, each AEV is expected to offset $148 in health costs and each PHEV $162. Lifetime savings are $1,185 and $1,296 for AEVs and PHEVs, respectively.

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\(^{45}\) The EV Project reports that AEVs average 9,000 miles annually. Similar to estimates of annual vehicles miles traveled per vehicle in Utah, as derived from the 2009 National Household Travel Survey: [http://nhts.ornl.gov/download.shtml](http://nhts.ornl.gov/download.shtml).

\(^{46}\) Sales-weighted average miles per gallon of model year 2013 vehicles, calculated in University of Michigan Transportation Research Institute Eco-driving Index, 2013: [http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html](http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html). This average includes all light duty vehicles (cars, SUVs, pick-up trucks) and may include a small number of alternative fuel vehicles. This estimate was the best available of model year 2013 vehicle operating efficiency.

\(^{47}\) Average operating efficiency of all electric vehicles included on the US EPA site [www.fueleconomy.gov](http://www.fueleconomy.gov) as of January 2014. This can be modified to include only those vehicles actually available in Utah.


\(^{50}\) Assumes 60% of miles powered by electricity.
Estimated health costs | Total annual health costs at 9,000 miles of travel
--- | ---
Conventional vehicle | $0.06/mile | $540
All electric vehicle | $0.145/kWh | $392
Plug-in hybrid electric | $0.145/kWh; $0.03/mile | $378

**Energy Security Costs**

The average new conventional vehicle uses 364 gallons of gasoline, annually, in Utah. The estimated economic costs, nationally, of reduced energy security that results from dependence on foreign oil are $0.42/gallon. Use of local and domestic electricity offsets this cost, resulting in an annual savings of $153 achieved through AEV use and $88 through PHEV use. Lifetime savings of improved energy security are estimated to be $1,224 for each AEV and $704 for each PHEV.

<table>
<thead>
<tr>
<th>Estimated energy security costs</th>
<th>Estimated annual gallons gasoline used</th>
<th>Annual energy security costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional vehicle</td>
<td>$0.42/gallon</td>
<td>364</td>
</tr>
<tr>
<td>All electric vehicle</td>
<td>$0.42/gallon</td>
<td>0</td>
</tr>
<tr>
<td>Plug-in hybrid electric</td>
<td>$0.42/gallon</td>
<td>209</td>
</tr>
</tbody>
</table>

**Measure Cost**

The incremental cost of an AEV, exclusive of home charging equipment, is approximately $5,000. The incremental cost of a PHEV is $5,500.

We estimate the average upfront cost of an equivalent conventional 2014 vehicle (fully loaded) to be $25,500, in accordance with the methods used in EPRI, 2013, adjusted for inflation. On average, the PHEV models used in this analysis (electric range of 21 miles) cost approximately $31,000. The Nissan Leaf, the most widely available AEV costs approximately $31,000. At this level, the mean incremental difference between a conventional and electric vehicle ranges from $5,000 to $5,500 as of 2014, using the most price recent data available, excluding AEV incentives and residential EVSE costs (see [http://www.afdc.energy.gov/vehicles/electric_availability.html](http://www.afdc.energy.gov/vehicles/electric_availability.html) for up to date information).

This price differential will change as the number of available electric models increases. Lease deals and current federal and state incentives make EVs considerably more affordable for consumers and in some cases such deals are

---

51 Health costs associated with PHEV use in gasoline mode are discounted due to higher than average mileage.


actually cheaper than the conventional ICE equivalent. However, because this analysis accounts for the full costs and benefits of AEV purchase and ownership, the full vehicle purchase price is used. The cost of a Level 1 (120 volt) residential EVSE is an additional cost of EV purchase and estimated to be $500 – $1,000 with installation.

**Operation and Maintenance Costs**

Total lifetime operation and energy savings are estimated to be:

<table>
<thead>
<tr>
<th></th>
<th>Operation costs (fuel/electricity)</th>
<th>Maintenance costs</th>
<th>Total lifetime costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional vehicle</td>
<td>$9,081</td>
<td>$648</td>
<td>$9,729</td>
</tr>
<tr>
<td>All electric vehicle</td>
<td>$2,173</td>
<td>$1,656</td>
<td>$3,829</td>
</tr>
<tr>
<td>Plug-in hybrid electric</td>
<td>$4,936</td>
<td>$2,520</td>
<td>$7,456</td>
</tr>
</tbody>
</table>

**Energy costs**

The deemed energy costs of an AEV average $271 annually and a PHEV $617, an average incremental savings of $864 and $518 annually, over conventional vehicle energy costs.

Annual estimates of gasoline prices and kWh were obtained from the Energy Information Administration 2013 Annual Energy Outlook (EIA 2013). Between 2014 and 2021, estimates of gasoline costs to power 9,000 vehicle miles range from $1,099 to $1,198 in 2011 dollars. These prices can be further modified for specific locations. AEV electricity costs range from $267 to $274 annually, and PHEV combined gasoline and electricity costs from $607 to $643 annually. Lifetime energy savings are estimated to be $6,908 for each AEV, and $4,145 for each PHEV.

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline</th>
<th>Electricity</th>
<th>Gasoline/Electricity Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>$1,116</td>
<td>$267</td>
<td>$607</td>
</tr>
<tr>
<td>2015</td>
<td>$1,099</td>
<td>$268</td>
<td>$600</td>
</tr>
<tr>
<td>2016</td>
<td>$1,100</td>
<td>$272</td>
<td>$603</td>
</tr>
<tr>
<td>2017</td>
<td>$1,110</td>
<td>$274</td>
<td>$609</td>
</tr>
<tr>
<td>2018</td>
<td>$1,129</td>
<td>$274</td>
<td>$616</td>
</tr>
<tr>
<td>2019</td>
<td>$1,151</td>
<td>$273</td>
<td>$624</td>
</tr>
<tr>
<td>2020</td>
<td>$1,178</td>
<td>$272</td>
<td>$634</td>
</tr>
<tr>
<td>2021</td>
<td>$1,198</td>
<td>$273</td>
<td>$643</td>
</tr>
<tr>
<td>Total</td>
<td>$9,081</td>
<td>$2,173</td>
<td>$4,936</td>
</tr>
</tbody>
</table>

**Maintenance costs**

Maintenance costs were considered for 8 years (warrantied battery lifetime) at 9,000 miles driven annually. Total maintenance costs for 72,000 vehicle miles are estimated to be $648 for an AEV, $1,165 for a PHEV and $2,520 for a conventional gasoline vehicle. Maintenance costs are calculated based on manufacturer suggested vehicle maintenance schedules. Overall maintenance costs of AEVs are expected to be lower than conventional vehicles due to fewer moving and mechanical parts. AEVs experience slower wear of brake pads due to regenerative braking, do not require oil changes, and do not have exhaust systems or clutches.

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54 Price projections were not located for Utah specifically but should be used here if available.
55 EPRI, 2013. Total Cost of Ownership Model for Current Plug-in Electric Vehicles. This document estimates maintenance costs for 100,000 vehicle miles. We discounted these costs by 28% to represent 72,000 miles of vehicle travel.
Referenced Documents

Aultman-Hall et al. 2012. Travel Demand and Charging Capacity for Electric Vehicles in Rural States. Transportation Research Record.


The EV Project. 2013. PEV Driver Responses to Time-of-Use Rates (TOU) while Charging EV Project Vehicles.


University of Michigan Transportation Research Institute Eco-Driving Index, October 2013: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html.


Appendix D

Customized Transportation TRM for the Burlington Electric Department

The following analysis is a Transportation Technical Reference Manual (TRM) customized for the Burlington Electric Department to characterize energy savings, environmental benefits, and financial costs of selected transportation efficiency measures in its service territory. It focuses on a single efficiency measure: a dispatchable electric vehicle (EV) demand response program that will allow for remote control of EV charging depending on wholesale electricity costs. Such a program would reduce EV contribution to peak load and ensure that any strain on the grid created by EV demand is minimized.

For the purposes of this report, the term electric vehicle (EV) refers to all plug-in vehicles—both all electric and plug-in hybrid. Predicting how EVs will impact electricity demand involves consideration of not only of how many EVs will be charging in the state (the amount of new demand), but what time of day charging will occur (during peak vs. off-peak hours), and how that demand will be spatially distributed. Nationally, over 350,000 EVs have been purchased. There were nearly 1,000 EVs registered in Vermont as of July 2015. The additional demand of one all electric vehicle load is estimated to be 2,700 kWh annually, approximately 39% of average household load in Vermont.

Our analysis provides the following key takeaways for the Burlington Electric Department (BED):

- EV participation in a BED demand response program could provide annual savings of $186 per vehicle, an amount anticipated to last many years.
- In addition to economic savings on wholesale energy purchases, reducing peak period loads will lessen the need for costly infrastructure upgrades.
- Current research activities may create opportunities to integrate demand response controls directly with in-vehicle telematics systems, which will reduce hardware costs and streamline program development.

EV Demand response program

There is potential for EVs to serve as a resource to the grid in the future, reducing the impact of additional demand and facilitating overall electric system efficiency. Broadly, EVs can be used in demand response programs to reduce peak demand or serve as distributed energy resources, storing excess energy during times of low demand and feeding it back to the grid during times of high demand, when electricity prices tend to be highest. Although two-way exchange of energy between vehicles and the grid is not yet operational beyond a number of demonstration projects, the potential of EVs to serve as demand response (DR) resources is a much more imminent possibility, primarily requiring technology already in existence for current DR programs. An EV DR program would need some element of communication between the vehicle or EV charging unit and the utility (or DR administrator) so that charging could be modulated in response to price signals, similar to any DR program. A pilot project in Victoria, Australia in 2013 successfully administered a number of voluntary DR events, achieving high rates of participation from EV drivers and smooth communication among the utility, charging unit, and drivers. DR programs can be very effective at achieving peak shaving and balancing load factors.

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57 Average household electricity use was 8,896 kWh in Utah in 2010, SWEEP 2014: [http://www.swenergy.org/publications/factsheets/index.html](http://www.swenergy.org/publications/factsheets/index.html)
TECHNICAL REFERENCE MANUAL

Definition of Efficient Equipment

Residential level 2 electric vehicle (EV) charging with a dispatchable demand response program

Definition of Baseline

Residential level 2 240 volt EV charging, no demand response program

Description of Proposed Efficiency Measure

This dispatchable demand response program will allow EV charging to be reduced or turned off remotely, when the wholesale cost of electricity exceeds a designated threshold. This program would reduce energy costs and load factor for the Burlington Electric Department and increase overall system efficiency.

Deemed Annual Energy Savings

In Burlington Electric territory, there were approximately 430 hours between July 1, 2013 and June 20\textsuperscript{th}, 2014 when the estimated total wholesale cost of electricity\textsuperscript{58} exceeded the estimated amount paid by BED residential customers (approximately $145/MWh) by over $100/MWh. Of these 430 hours, the average cost difference between the wholesale cost and the cost to BED residential customers was $186.62/MWh. Each EV uses an average of 5 kWh per hour.\textsuperscript{59} Per vehicle, if an entire hour could be offset, each vehicle would save an estimated $0.93 in electricity costs for BED. If a single vehicle participated in a total of 200 hours over the course of the year, this would save the utility approximately $186. At higher rates of EV penetration and participation, approximately 1,000 vehicles participating for 200 hours annually, would result in $18,600 in avoided energy costs for BED. Greenhouse gas savings will depend on the mix of generating sources, especially the peak generating mix.

Assumptions and supporting calculations

Peak load shifted per EV: 5kWh per hour
Average value of avoided energy costs per kWh: $0.186
Average of peak load shifted, per vehicle per hour: (5 kWh) x ($0.186)= $0.93

Incremental price difference

Dispatchable meters are estimated to be $200-$500 each. Automakers are currently working with the electric power industry to explore centralized control systems built into existing vehicle communication systems which will significantly reduce or eliminate the incremental price difference to participate\textsuperscript{60}. Other program costs will include any payments made to customers for participation, and program administration costs which will vary depending on program specifics.

Persistence

1.0- The peak savings are not expected to decline with time.

\textsuperscript{58}From ISO-NE: \url{http://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/wlsecost-hourly-vermont}

\textsuperscript{59}Based on average charger capacity of available EVs.

\textsuperscript{60}EPRI Open Platform for Plug-in Vehicle-Grid Integration: \url{http://www.epri.com/Our-Portfolio/Pages/Portfolio.aspx?program=053122#tab=2}
Coincidence Factor

Coincidence factor should be close to zero: this measure will reduce peak demand.
Appendix E

CUSTOMIZED TRANSPORTATION TRM FOR A VERMONT DISTRIBUTION UTILITY

Distribution utilities in Vermont have begun to explore an EVSE program to provide support for electric vehicle (EV) charging stations in the state’s 24 designated downtown locations. This analysis focuses on public DC Fast Charging as a means of reducing fossil fuel usage in the state, and facilitating the transition to electrified transportation. A potential utility program would support installations and technical assistance. Broadly, in assessing the cost-effectiveness of public DC fast charging stations for electric vehicles, we consider: the cost of charging equipment and installation, electricity costs, offset gasoline costs, avoided greenhouse gas (GHG emissions), and avoided health impacts of tailpipe emissions.

Our analysis resulted in the following key findings and takeaways for Vermont distribution utilities:

- Distribution utilities engaging in programs to reduce greenhouse gas and/or fossil fuel reduction programs supporting DC Fast Charging EVSE installations can expect a reduction of 17.5 tons CO₂ avoided annually.
- DC Fast Charging stations distribute more electricity and enable more vehicle miles traveled on electricity than other types of EVSE, so are more likely to pass efficiency measure cost effectiveness screening tests.

PUBLIC DC FAST CHARGING ELECTRIC VEHICLE SUPPLY EQUIPMENT AT A DOWNTOWN LOCATION

Definition of Efficient Equipment: DC Fast Charging Electric Vehicle Supply Equipment at a public or commercial location in a designated downtown

Definition of Baseline: Use of a conventional gasoline vehicle

Description: Electric Vehicle Supply Equipment (EVSE) is the infrastructure that is used to charge electric vehicle batteries. DC Fast charging provides a charge to all electric vehicles equipped with this capability in approximately 20 – 30 minutes. These fast-charging stations enable longer-distance travel by vehicles equipped with fast charging ports. EV models that can use fast charging ports include: the Chevrolet Spark EV, Nissan LEAF, Kia Soul EV, Mitsubishi iMiEV, BMW i3, Tesla Model S and Volkswagen eGolf. There are three varieties of fast charging ports with Asian manufacturers using CHAdeMO, European and US automakers using SAE Combo and Tesla’s Supercharger. Many EVSE manufactures are now supplying DC Fast Charging equipment with multiple plug connections on the same unit to provider broader compatibility.

This measure quantifies the energy and GHG savings of a DC Fast charging installation relative to a baseline of a conventional gasoline vehicle. Each mile powered by electricity is assumed to offset a mile powered by gasoline. Energy savings will depend upon use: the more an EVSE is used, the more gasoline that will be offset. The EVSE included in this measure are limited to installations in designated downtown areas to maximize usage rates.

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61 A complete list of the state’s designated downtowns can be found here: http://accd.vermont.gov/strong_communities/opportunities/revitalization/downtown/list
### Summary of monetized lifetime (10 year) savings relative to baseline

<table>
<thead>
<tr>
<th>Factor</th>
<th>DC Fast Charger Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVSE unit cost, including installation</td>
<td>$30,000</td>
</tr>
<tr>
<td>Net energy savings (MMBtu)</td>
<td>$18,310 (761)</td>
</tr>
<tr>
<td>Net CO$_2$ emissions savings (tons)</td>
<td>$17,500 (175)</td>
</tr>
<tr>
<td>Avoided health impacts</td>
<td>$9,990</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>-$4,000</td>
</tr>
<tr>
<td>Total lifetime monetized savings</td>
<td>$11,710</td>
</tr>
</tbody>
</table>

### Deemed Annual Energy Savings:

Net annual energy savings will be 76.12 MMBtu per unit, and 843 gallons gasoline will be avoided annually. (Savings will vary depending on the amount of charging done at a particular EVSE).

Data from the EV Project, a national, multi-year study of EV driving and charging behavior\(^{62}\), show that in 2013, nationwide, public DC Fast chargers were used for an average of 2.32 charges per day for total energy usage of 6,093 kWh, powering an estimated 19,215 miles. This compares to an average energy usage of 564 kWh for Level 2 EVSE, powering 1,776 miles, or about 10% of the energy used by DC Fast Chargers.

- \((6,093 \text{ kWh}) \times (3.15 \text{ miles/kWh average EV efficiency}) = 19,192 \text{ miles annually}\)
- \((19,192 \text{ miles}) \times (1 \text{ gallon /22.8 miles average vehicle fuel efficiency}) = 843 \text{ gallons gasoline}\)
- \((843 \text{ gallons gasoline}) \times (0.115 \text{ MMBtu/gallon gasoline}) = 96.92 \text{ MMBtu}\)
- \((6,093 \text{ kWh}) \times (1 \text{ MMBtu/kWh}) = 20.8 \text{ MMBtu used annually}\)
- \(\text{Annual energy savings} = 96.92 \text{ MMBtu} – 20.8 \text{ MMBtu} = 76.12 \text{ MMBtu}\)

Estimates of public EVSE usage should be updated as EV adoption grows and more public EVSE units begin charging fees, factors which may affect usage patterns.

### Other Savings:

Like energy savings GHG emission reductions will vary with the amount of EVSE usage but an overall lifetime reduction of 175 tons is expected, based on the electricity generating mix in New England. Replacing 843 gallons of gasoline use with miles powered by electricity would amount to 17.5 tons CO$_2$ avoided annually and $999 in health impacts avoided. As described in the introduction, health impacts include healthcare costs and reduced productivity due to respiratory ailments induced and aggravated by emissions from tailpipes and electricity generation. Lifetime health impact costs avoided over the ten year lifetime of each EVSE is estimated to be $9,990.

- \((843 \text{ gallons gasoline offset}) \times (23.4 \text{ lbs CO}_2/\text{gallon}) = 19,726 \text{ lbs CO}_2 (19.7 \text{ tons}) \text{ avoided annually}\)
- \((6.093 \text{ MWh electricity used annually per EVSE unit}) \times (734 \text{ lbs CO}_2/\text{MWh delivered electricity in the New England subregion}^{63}) = 4,472 \text{ lbs CO}_2 (2.2 \text{ tons}) \text{ produced annually}\)
- \(\text{Net CO}_2 \text{ emission reductions} = 17.5 \text{ tons avoided annually}\)
- \(\text{Lifetime avoided net CO}_2 \text{ emissions through DC Fast charging units= 175 tons}\)

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\(^{62}\) See the EV Project at: [www.theevproject.com](http://www.theevproject.com) and [http://avt.inel.gov/evproject.shtml](http://avt.inel.gov/evproject.shtml).

\(^{63}\) EPA eGrid data files, New England subregion: [http://www.epa.gov/cleanenergy/energy-resources/egrid/](http://www.epa.gov/cleanenergy/energy-resources/egrid/).
- Health impacts of avoided gasoline usage = (19,192 miles) x ($0.06 / mile) = $1,151 avoided
- Health impacts of increased electricity = ($0.025 / kWh) x (6,093 kWh) = $152 additional health impacts annually
- Net health impacts = $999 avoided health impacts annually

Measure Cost:

Estimates of DC Fast Charging equipment costs vary between $13,000 and $40,000, varying by model and functionality. Most units start at ~$15,000 - $20,000. Because the electricity draw of DC Fast chargers is greater than lower powered EVSE, owners are more likely to charge users a fee, especially in anticipation of increased use in coming years. Linking into a network, such as ChargePoint that provides unit owners the ability to track usage and collect user fees costs an estimated $350 per year per unit. Installation costs also vary widely, between $5,000 to upwards of $15,000 with site specific considerations, such as distance to power source and any trenching of conduits that must occur.

Operation and Maintenance Costs: Maintenance costs of each EVSE unit are estimated to be $400 annually.64

Operational costs (total electricity costs) are estimated to be $7,800 over the lifetime of the measure (accounting only for electricity costs and not associated demand charges).65 Lifetime operational costs of baseline (conventional vehicle use to power 19,192 miles each year) is estimated to be $26,110.66 Net operational savings per EVSE unit is estimated to be $1,831.

Coincident Factor: 75%: Most use of commercial EVSE occurs during business hours 9-5, and will thus add to peak load (although definitions of ‘peak’ can vary by utility territory). Region specific data of charging behavior at public EVSE may be available through The EV Project (www.theevproject.com).

Persistence: 1.0. The relative operating efficiency of electric vehicles relative to conventional may vary with federal regulations and general trends in consumer purchasing patterns. The average fleet efficiency should be re-assessed periodically.

Measure Lifetime: 10 years (typical length of service support for EVSE; see individual EVSE manufacturer websites)

Spillover and Free Ridership: N/A

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