NREL
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Modeling Framework and Results to Inform Charging Infrastructure Investments

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VAN025

NREL/PR-5400-68370

Overview

Timeline	Barriers
Start: October, 2014 End: September, 2017* Status: 75% complete * Project continuation determined by DOE	A. Availability of alternative fuels and electric charging station infrastructure. C. Consumer reluctance to purchase new technologies. E. Maintenance of local coalition effectiveness.

Budget	Partners
Economic Value Assessment: $250k (FY15: $200k, FY17: $50k) Infrastructure Assessment: $350k Total Funds Received to Date: $600K	Edison Electrical Institute (EEI; NEVA review) Massachusetts Executive Office of Energy and Environmental Affairs City of Columbus, Ohio California Energy Commission • *Helped fund and develop initial EVI-Pro model* Electric Power Research Institute (EPRI) U.S. Department of Transportation U.S. Environmental Protection Agency Others listed by project in slides below

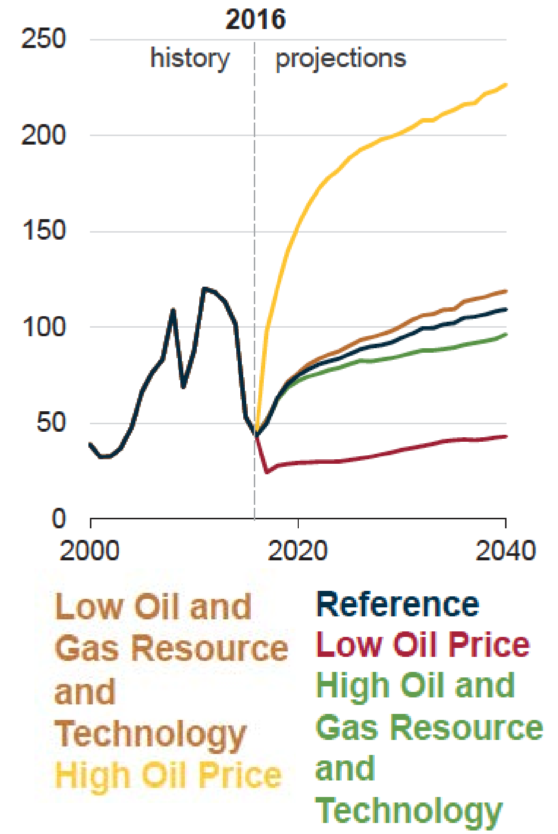
Improving national energy security and maintaining household fuel savings through effective EVSE deployment

- **The transportation sector is dominated by petroleum fuels dependent upon a volatile global market**
  - Studies suggest a significant economic penalty due to continued reliance on imported petroleum, on the order of $100 billion to $400 billion per year (Liu, Greene and Lin, 2015 AMR Presentation)
- **Substituting electricity for gasoline and diesel fuels can improve energy security**

Research Goal: An improved understanding of the role of electric vehicle supply equipment (EVSE) in the increased market adoption of plug-in electric vehicles (PEVs) and increased electric-miles (e-miles), contributing to the goal of improving national energy security.

More effective and focused deployment of EVSE can enhance the capacity for PEV market growth to improve energy security while maintaining fuel savings for households

The wide range in oil price projections ($2016/bbl) in the near-term suggests volatility will persist into the future

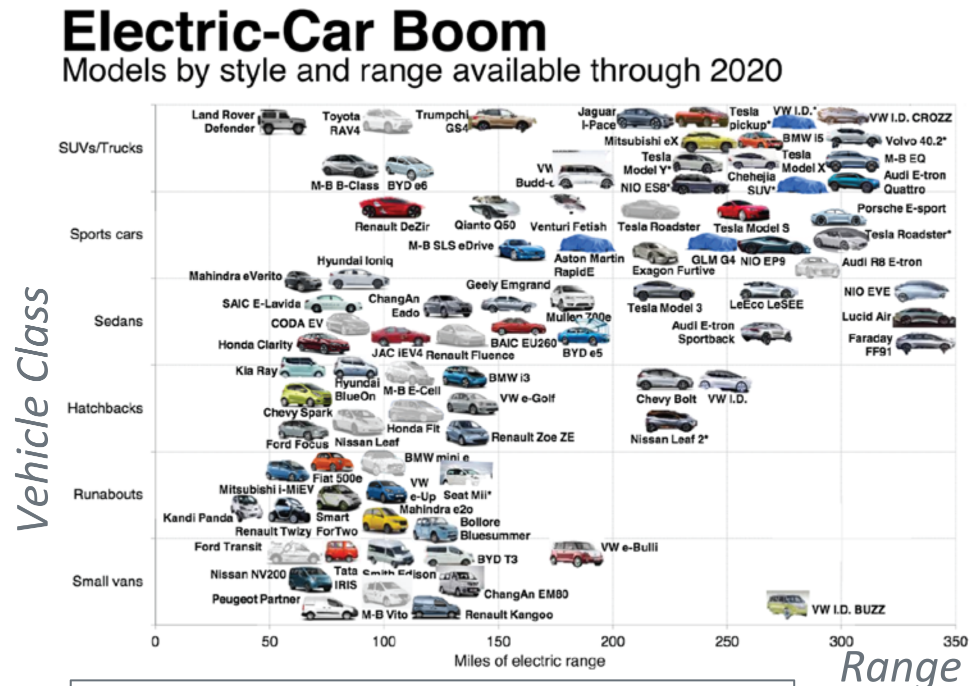


Annual Energy Outlook 2017
https://www.eia.gov/outlooks/aeo/

The deployment of EVSE must anticipate future PEV innovations while remaining cost-effective

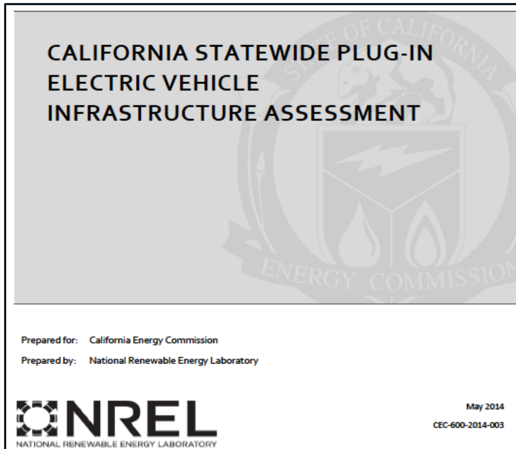
- Innovations in PEV configurations, styles, and all-electric range are changing rapidly
- Both future battery costs and consumer preferences for different vehicle attributes are uncertain
- The most effective deployment of EVSE in supporting PEV markets will depend upon how these trends evolve over time
- **Various stakeholders must anticipate a range of possible future trends in order to develop cost- and market-effective EVSE deployment plans**

Scenario analysis and market simulation methods can be used to inform stakeholders during the EVSE planning process



Source: Bloomberg New Energy Finance (Randall 2017)

The ***California Energy Commission's Statewide PEV Infrastructure Assessment*** report is an example of scenario analysis developed at the state level (CEC 2014).



Five analysis projects contribute to the research goal

Milestones

National Economic Value Assessment (NEVA)
How does the balance of total costs and benefits compare with high PEV market share achieved by 2035?
Complete

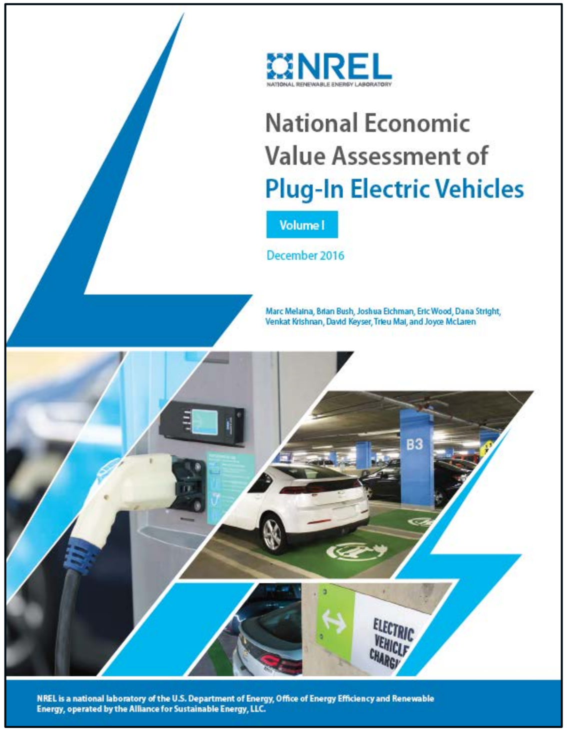
Massachusetts EVSE Case Study
Estimating EVSE requirements for future PEVs.
Complete

National Corridor Assessment
EVSE along major long-distance corridors.
Ongoing

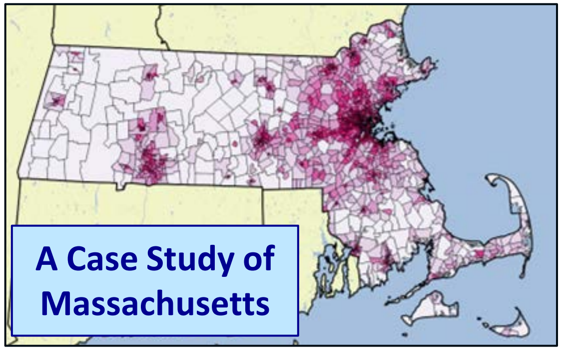
Columbus PEV Infrastructure Scenario Analysis
Collaborative scenarios developed with input from multiple local and industry stakeholders.
Ongoing

PEV Infrastructure Analysis Tool
Generic, simple tool designed to be used by various end-users.
Ongoing

Each project draws upon similar core analytic methods & data



http://www.afdc.energy.gov/uploads/publication/value_assessment_pev_v1.pdf



Wood et al. 2017

NEVA's Basic Cost and Benefit Estimates

Approach 1

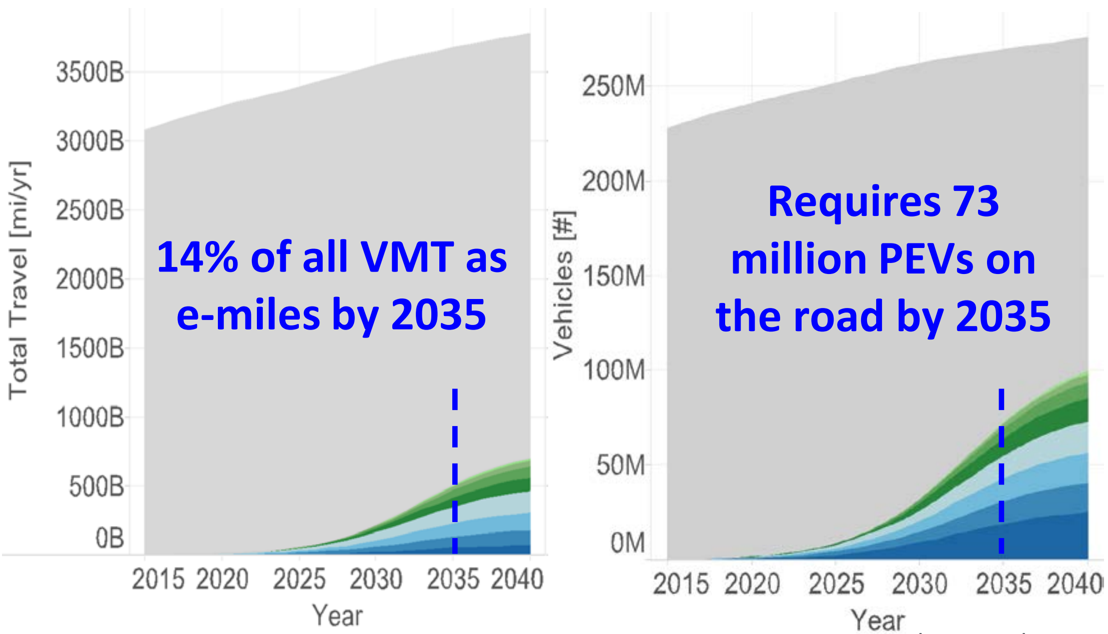
COMPONENTS OF THE NEVA COST AND BENEFIT CALCULATIONS

Costs	**Benefits**
Incremental PEV costs	Household gasoline savings
EVSE Costs	Petroleum reductions
	GHG reduction benefits

Total social benefits = Private + Social

Calculations are resolved at the census division level

PEV VMT and Market Growth Trends (main scenario)



Melaina et al. 2016

The 14% e-mile assumption is a scenario design input assumption, comparable to a 2013 National Academy study

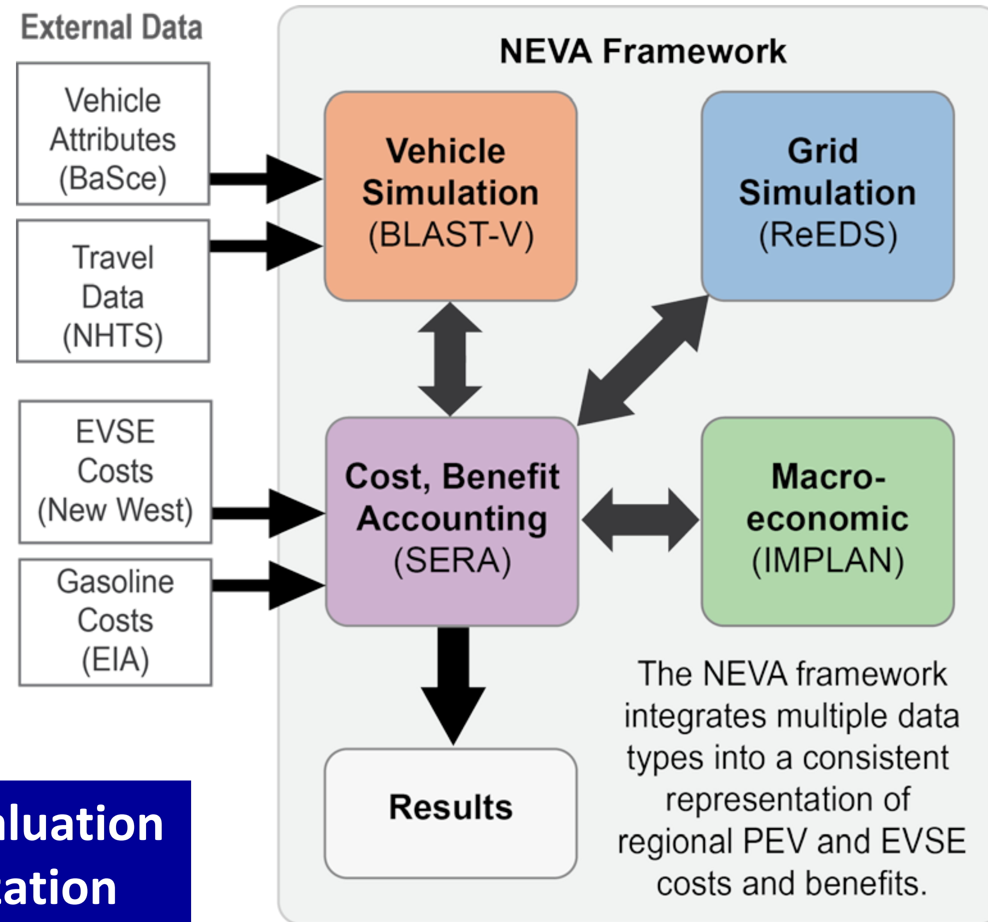
CV: Conventional gasoline vehicle
HEV: Hybrid electric gasoline vehicle
BEV: Battery electric vehicle
PHEV: Plug-in hybrid electric vehicle
PEV: Plug-in Electric Vehicle (includes BEVs & PHEVs)
VMT: Vehicle miles travelled

NEVA Study Framework

The diagram at right indicates main data sources and framework modules applied to develop scenario results.

Major novel analytic methods include the following:

- Nationwide vehicle simulations based upon regional variations in household travel patterns (NHTS), climate, and fuel prices.
- Feedback with grid simulations (ReEDS) to determine PEV demand influence on prices and GHGs.



Melaina et al. 2016

The Scenario Evaluation and Regionalization Analysis (SERA) model integrates and resolves regional results from various sub-modules.

Acronyms

BaSce: Baseline Scenario (vehicle cost and performance)
NHTS: National Household Travel Survey
EIA: Energy Information Administration
BLAST-V: Battery Lifetime Analysis and Simulation Tool
ReEDS: Renewable Energy Deployment System

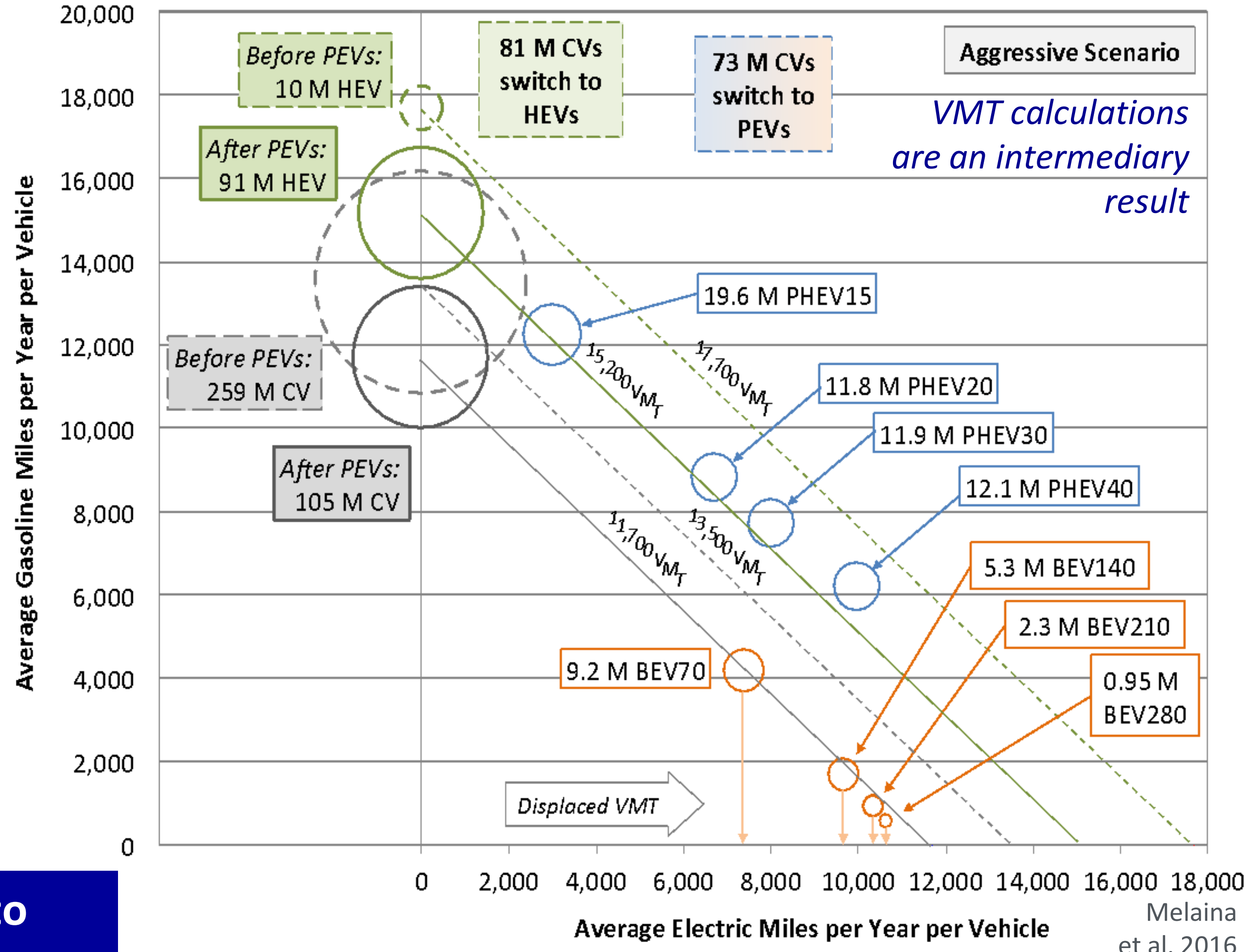
NEVA: Resolving allocation of PEVs to households where they provide the greatest economic benefit

Approach 3

NEVA assumes 14% of all light-duty vehicle (LDV) vehicle miles traveled (VMT) are e-miles by 2035.

This results in 73 million PEVs on the road by 2035.

However, the benefits provided by different types of PEVs depends significantly on regional gasoline and electricity prices, climate, and household travel patterns.



BEVs tend to be allocated to households requiring fewer long-distance trips and therefore less than average annual VMT, while PHEVs go to high-VMT households.

The figure above indicates VMT per year by conventional vehicles (large grey circle) with arrows showing the redistribution of VMT after introducing HEVs, PHEVs, and BEVs. BEV households rely on second vehicles for long-distance trips, requiring some gasoline miles (Y axis).

EVI-Pro is used in Massachusetts Case Study and Columbus, Ohio, EVSE requirements study

Approach 4

Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

PEV driving/charging simulator + **Real-world** travel profiles

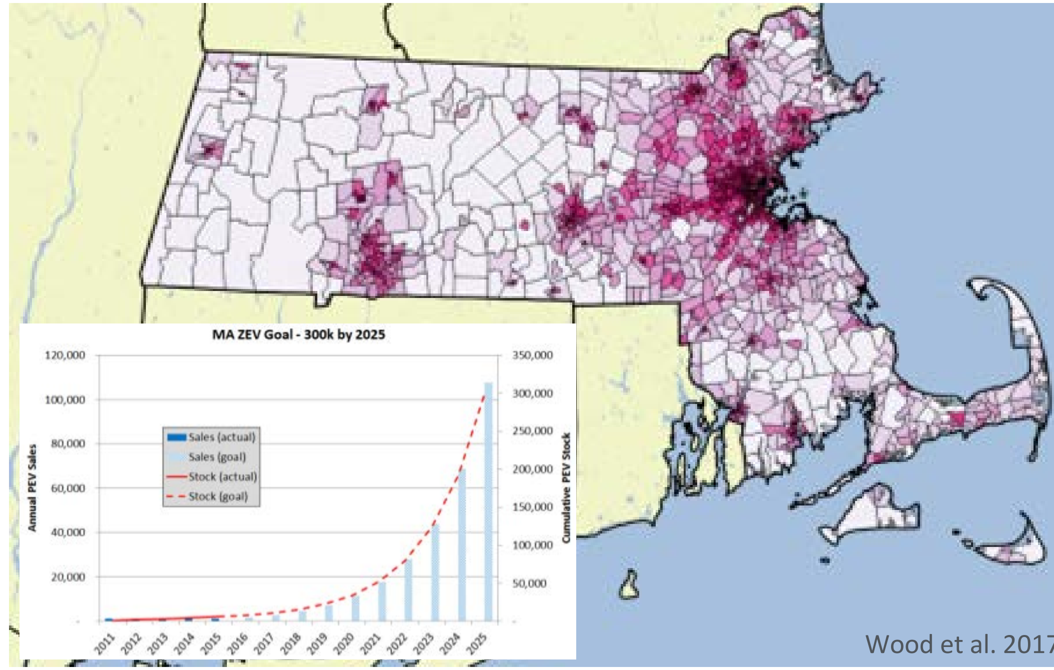
Economically efficient consumer charging behavior

Estimates EVSE requirements for

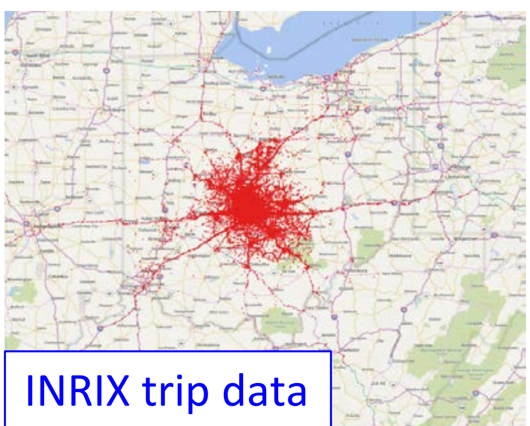
- PHEV and BEV powertrains
- Single- and multi-unit dwellings
- Weekday and weekend travel

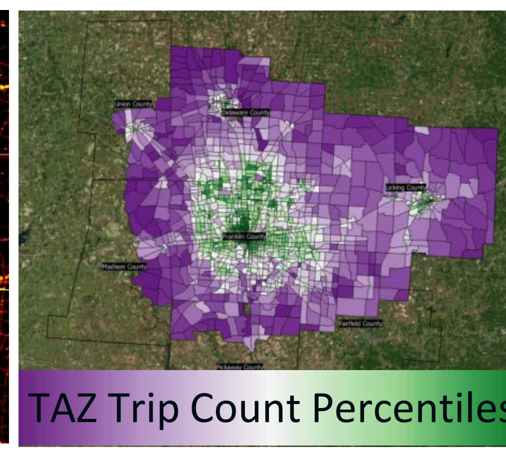
EVI-Pro has been developed by NREL and the California Energy Commission

EVI-Pro: MA state goal of 300,000 PEVs by 2025



Columbus study draws upon multiple data sources



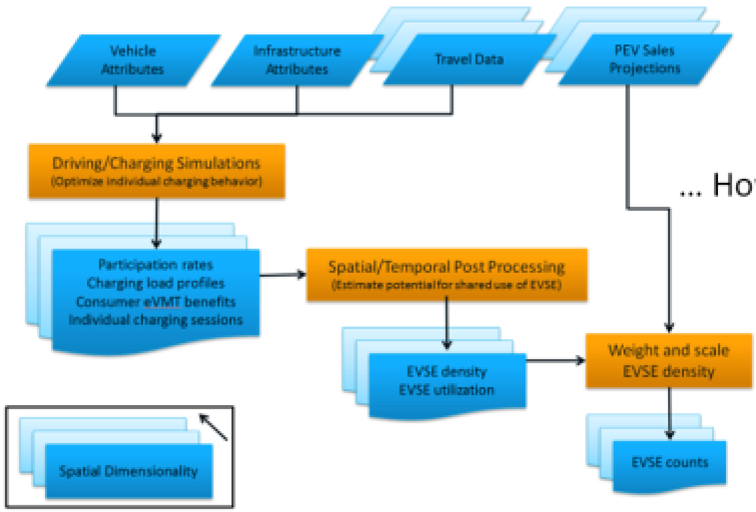


Approach 5

Overview of the Analytic Approach

If X million PEVs are on the road…

Input



… How many charging stations do we need?

Output

Detailed Inputs

PEV Penetration Levels: 5% to 40%
PEV Dispersion: Regional and National
BEV Driving Range: 100 to 300 miles
DCFC Power: 50kW to 350kW
BEV/PHEV mix: 50/50 and 80/20
Charging Preferences: Home/Work/Public
MUD adoption rates: Low/Mid/High
Station Cost Estimates: Low/Mid/High
National Travel Data from DOT FHWA

Driving/Charging Simulation

NREL's Electric Vehicle Infrastructure Projection Tool ***(EVI-Pro)*** *simulates consumer driving/charging behavior using real-world travel data. Special attention is paid to consumers with potentially inconsistent access to home charging, including residents of multi-unit dwellings. Methodology is consistent with academic literature and results have been successfully validated to existing data in California and Massachusetts.*

Detailed Outputs

Stations by Location: Home/Work/Public
Stations by Type: L1/L2/DCFC
Stations by Region: State-level, urban/rural
Prioritization of National DCFC Corridors
(distance between DCFC complexes)
Potential investment scenarios
Projected usage of public charging systems

Input assumptions, travel data, and modeling methodology to be reviewed with stakeholders prior to running analysis.

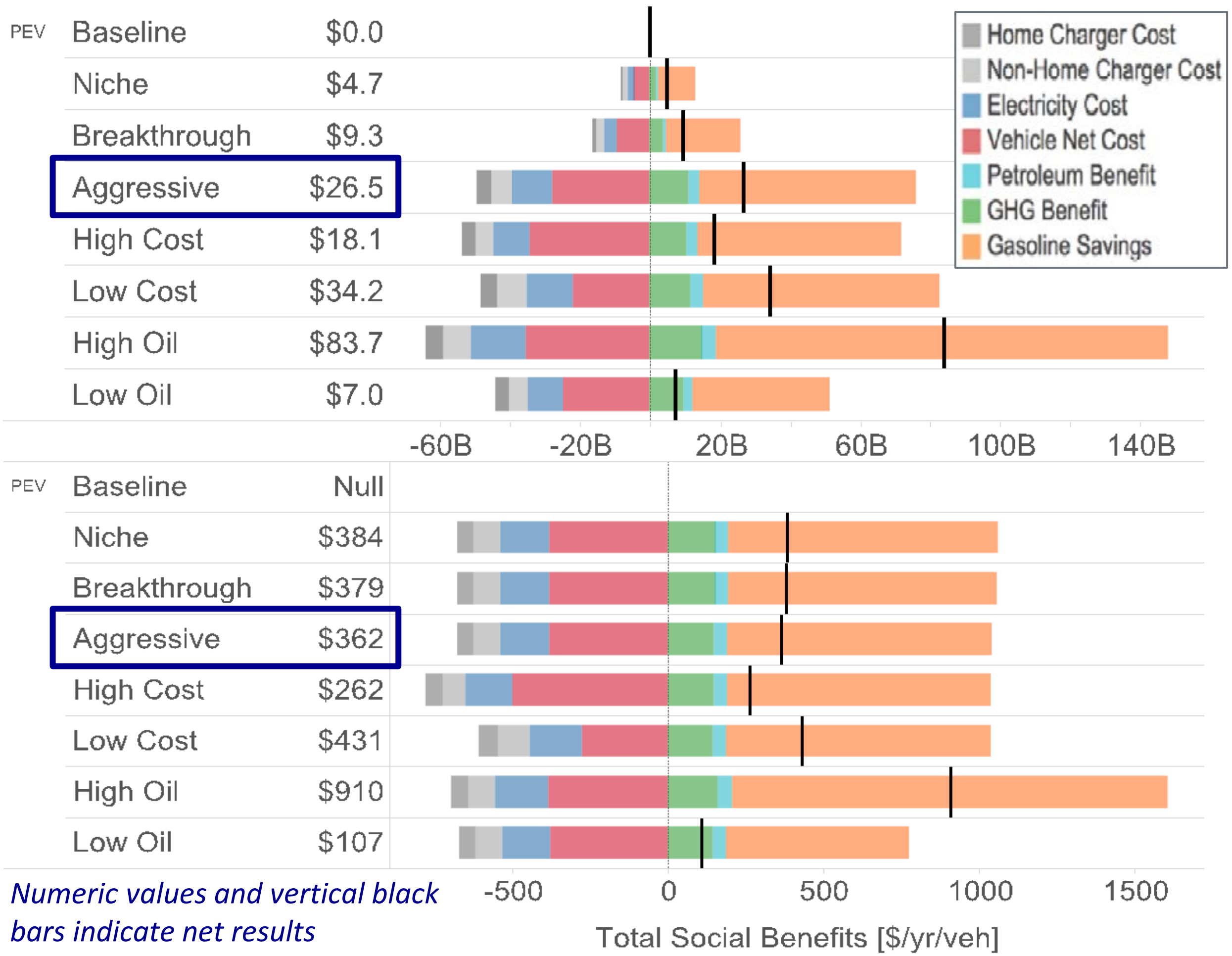
Focus on EVSE requirements to fulfill long-distance trips between (and through) multiple networked urban areas

NEVA Results: Net Total Social Costs & Benefits

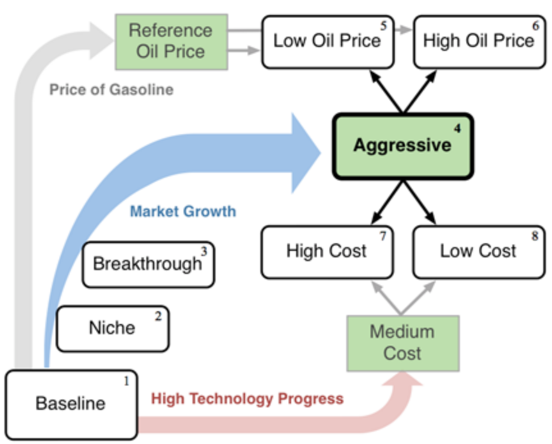
The NEVA scenarios assume relatively optimistic trends for PEV cost and performance to achieve high future market shares (BaSce inputs).

All scenarios result in positive net social benefits for increased PEV adoption.

The main Aggressive scenario achieves a positive benefit of $26.5 billion per year by 2035 (equal to $362 per PEV per yr).



Numeric values and vertical black bars indicate net results



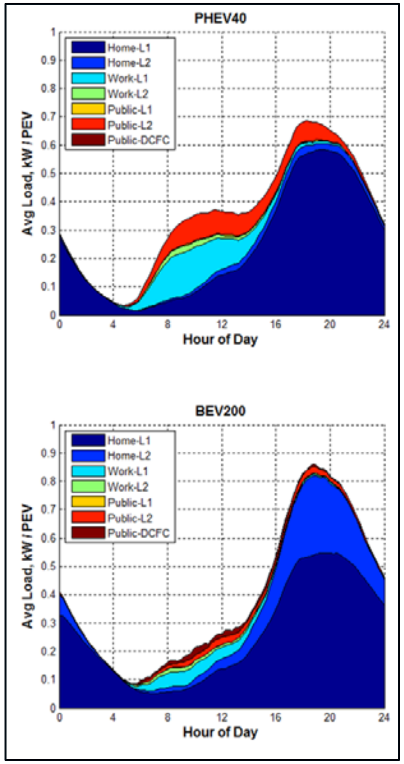
Left figure shows how scenarios are developed through variations from the Baseline scenario, which assumes minimal PEV market growth.

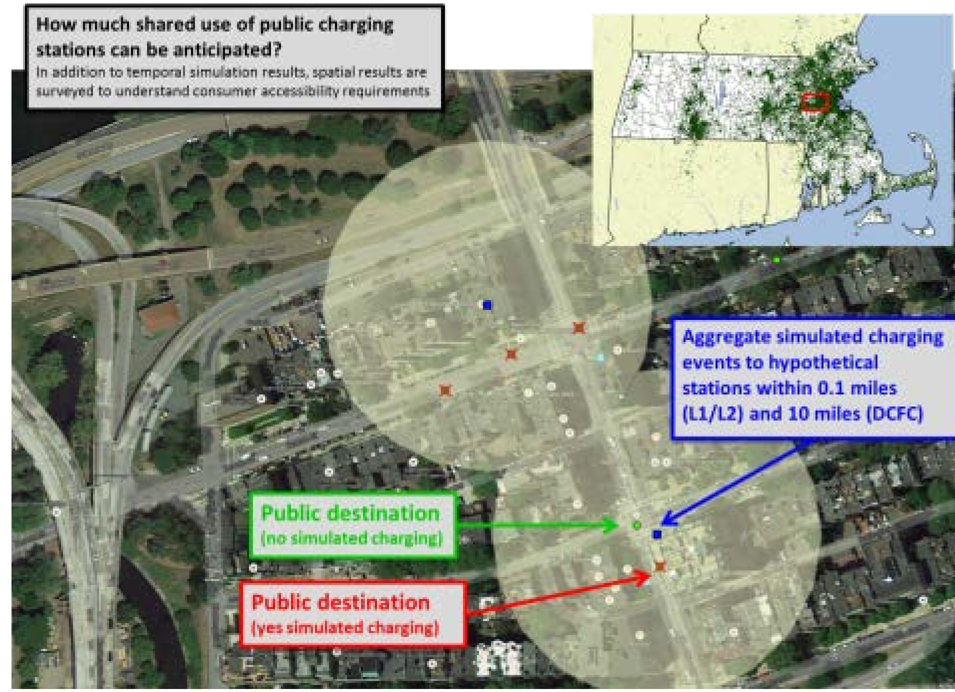
NEVA results are also presented by PEV type and Census Division.

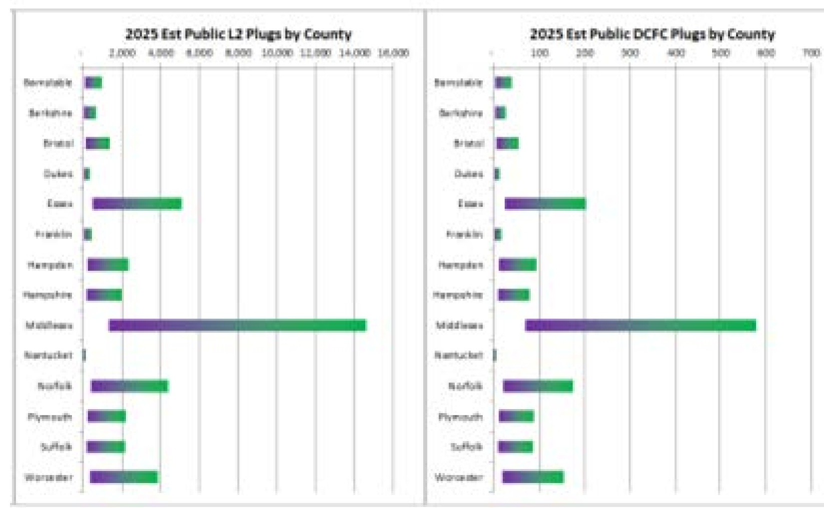
Massachusetts Case Study

Objective: To provide guidance on PEV charging infrastructure to regional stakeholders using a case study of Massachusetts meeting their ZEV goal of 300,000 PEVs by 2025.

Approach: Superimpose existing regional driving data with simulated PEVs and identify work/public EVSE requirements that meet anticipated consumer demand.







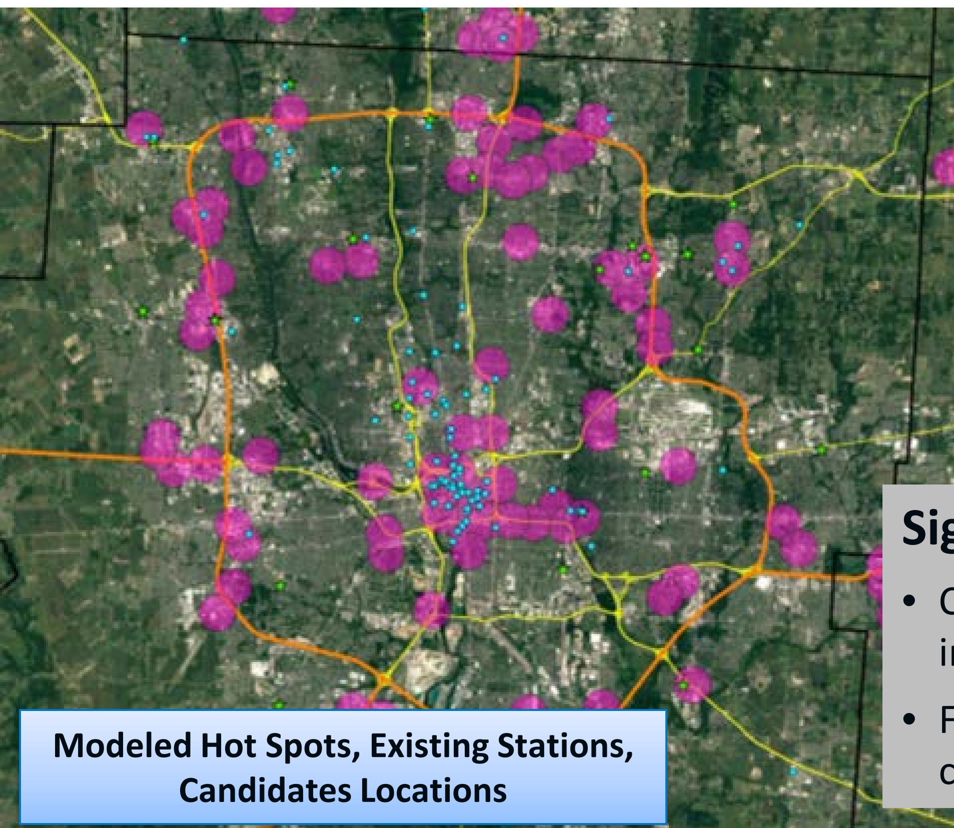
Significance & Impact

- Massachusetts Executive Office of Energy and Environmental Affairs is using projections to assist in planning statewide EVSE growth supporting PEVs.
- Related organizations have inquired on the potential to run similar analysis in additional states.

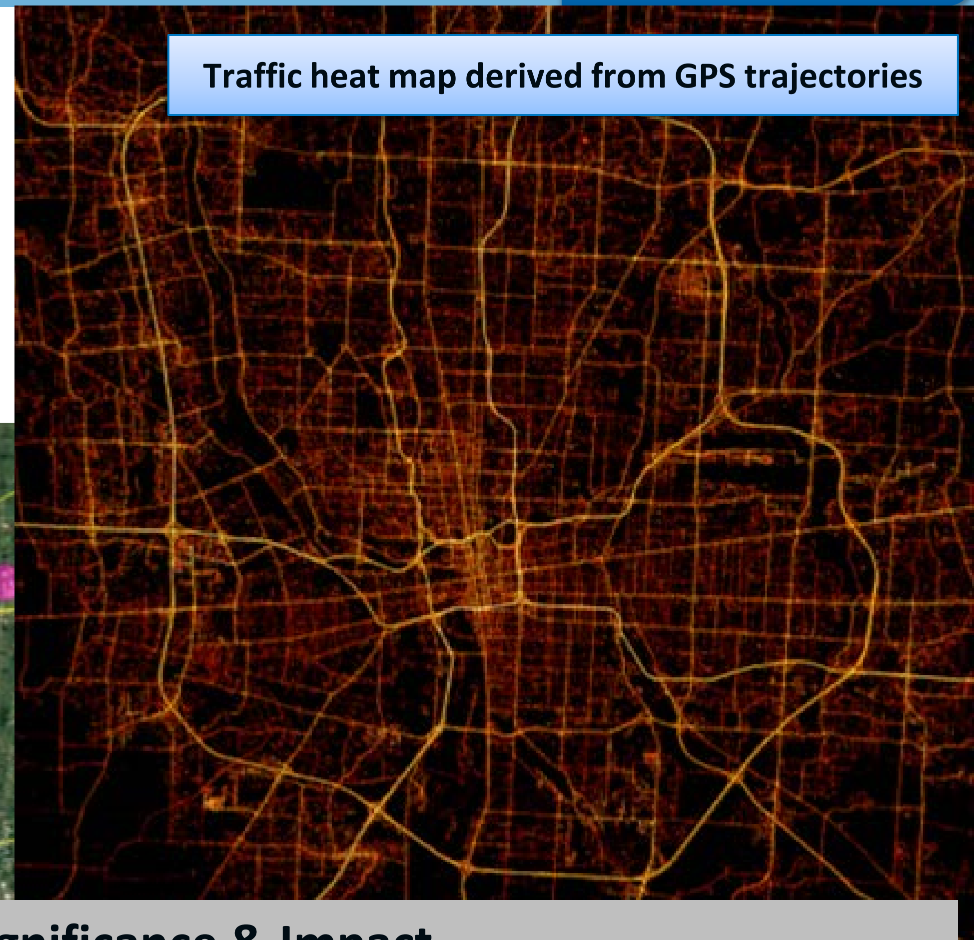
Columbus Scenario Analysis

Objective: Support DOT Smart City (Columbus, OH) plan an expanded EVSE network to reduce range anxiety as a barrier to PEV adoption and ensure effective use of public/private investments.

Approach: Simulate consumer PEV driving/charging behavior to identify locations with high estimated future demand for EVSE.



Modeled Hot Spots, Existing Stations, Candidates Locations



Traffic heat map derived from GPS trajectories

Significance & Impact

- City of Columbus is using preliminary results to assist in identifying site hosts for new EVSE installations.
- Final report will serve as a template for planning PEV charging stations in Columbus and other Smart Cities.

National Corridor Assessment

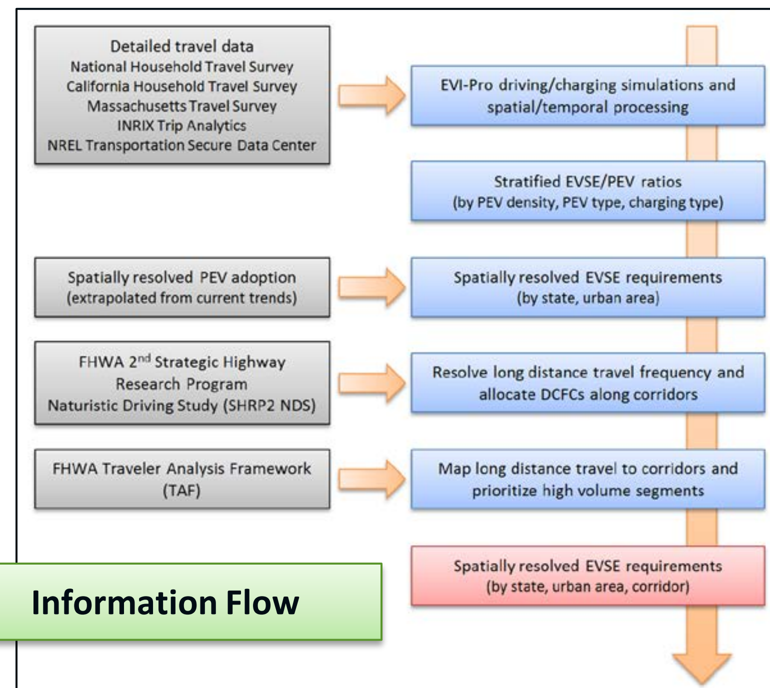
Objective: Develop a framework for estimating PEV infrastructure requirements for a national network of community/corridor chargers. The network should support both long distance inter-city travel and the increased use of electric transportation within urban areas.

Approach: A scenario-based methodology that enables exploring the impact of a number of variables with known sensitivities to PEV infrastructure requirements.

Significance & Impact

- Methodology white paper has been circulated to industry stakeholders to elicit upstream feedback, including to a number of automotive manufacturers, charging network operators, electric utilities, and government organizations
- Results are expected to inform near-term, national investment decisions

Long distance corridors connecting urban areas



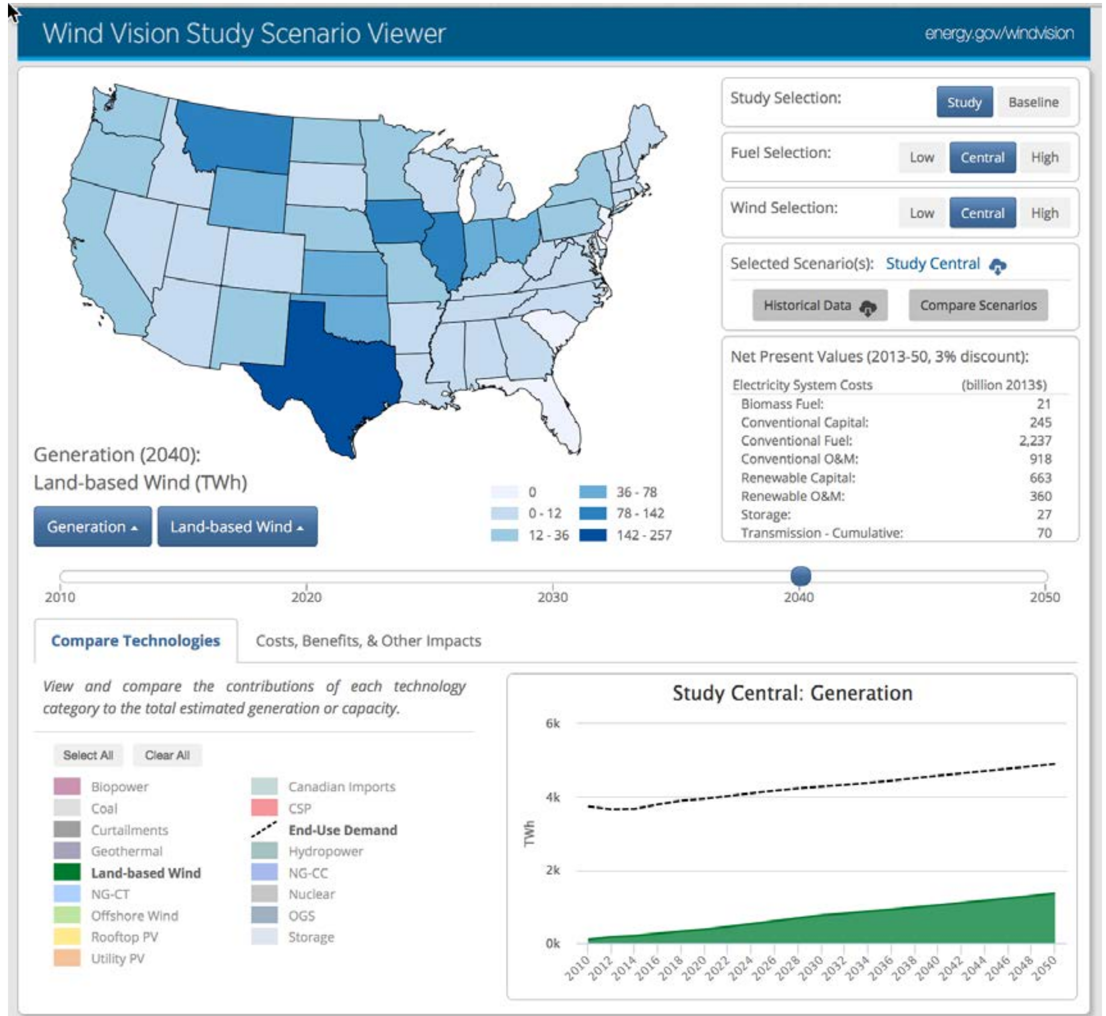
Information Flow

Simplified EVSE Assessment Tool: Web-based approach

The goal of this tool is to provide a quick assessment of EVSE requirements for a city or state using existing public data sources

- The analytic capabilities of the EVI-Pro model will be conveyed through a user-friendly web portal.
- The portal will be based upon the same scenario exploration framework used in other studies involving multiple selection criteria and large volumes of output data.
- The Wind Vision website shown at right is an example of this type of web portal.
- The portal is being tailored to the State of California in support of the California Energy Commission (through a non-DOE project).

The simple tool will allow rapid estimates of EVSE needs based on multiple input variables.



The Wind Vision Study Scenario Viewer above is an example of the user interface to be developed.
http://en.openei.org/apps/wv_viewer/

Response to previous year's AMR review comments

This project was not reviewed in any previous AMR meetings.

Collaboration

The following stakeholder groups contributed to each project listed below.

NEVA Study

- Edison Electric Institute

Massachusetts

- Massachusetts Executive Office of Energy and Environmental Affairs, California Energy Commission, Electric Power Research Institute (EPRI)

Columbus

- City of Columbus, Ohio State University, U.S. Department of Transportation, MORPC, Clean Fuels Ohio, Ohio EPA, AEP, Honda

National Corridor Assessment

- U.S. Department of Transportation, U.S. Environmental Protection Agency, ElectrifyAmerica, Ford, GM, Tesla, Electric Power Research Institute, Sacramento Municipal Utility District (SMUD), (others to be added over time)

The EVSE analysis methods and results from this projects are also supporting infrastructure analysis tasks within the SMART Mobility project, especially the Urban Science and Alternative Fuel Infrastructure pillars.

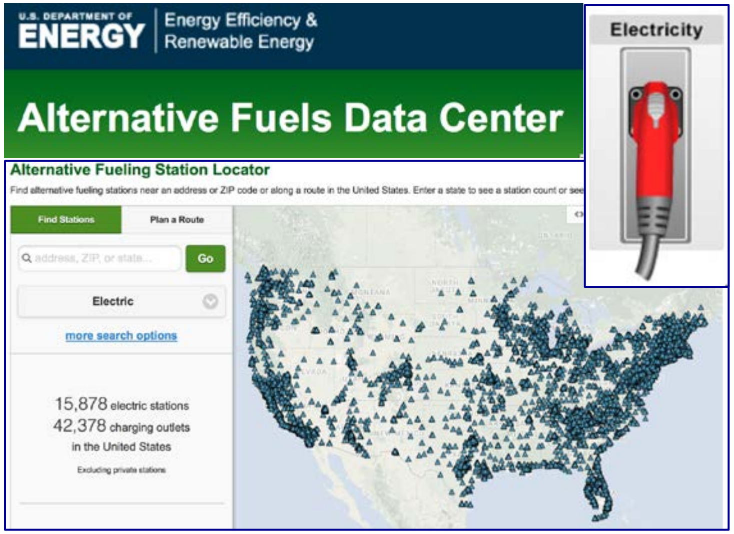
Remaining Challenges and Barriers

- **<u>Vehicle Choice Modeling</u>**: A more formal approach to assessing the costs and benefits associated with PEVs would involve a comparison between a consistent policy support framework (city, state or otherwise) and a Business as Usual scenario.
  - This "with" and "without" approach could inform policy makers directly on the merits of different policy design options.
- **<u>Future PEV Market Outcomes</u>**: For modeling infrastructure requirements, uncertainty regarding PEV sales and consumer charging behavior are challenges. This is addressed in each study using sensitivity analysis to quantify impacts of input parameters that are inherently uncertain.
  - This challenge will gradually be overcome as additional market data are collected on PEV sales and EVSE operations.
- **<u>Travel Data</u>**: Lack of comprehensive, spatially-resolved travel data is a limitation of the national study. This is being overcome by assembling composite datasets from multiple sources and extrapolating as necessary.

Proposed Future Work

- The analytic representation of PEV adoption could be improved with a more robust vehicle choice model, such as ADOPT, MA3T, etc.
  - EVSE availability could be integrated with a vehicle choice modeling using the SERA framework.
- Additional market data is needed to better understand the relationships between increased EVSE availability and:
  - (1) Consumer demand for PEVs
  - (2) Additional e-miles driven
- Planning activities should be informed on the effectiveness of different EVSE strategies with respect to market growth and social benefits.
  - Collection of real-world data on EVSE usage will improve the realism of forward-looking models.
  - Feedback from Clean Cities and other municipal or state agencies can improve analytic focus.

Market Acceptance of Advanced Automotive Technologies (MA3T) Model
(Oak Ridge National Laboratory)



http://www.afdc.energy.gov/

Summary

Relevance

- PEV adoption can enhance energy security and increase household fuel savings
- Stakeholders must anticipate a wide range of outcomes as technologies evolve

Approach

- Five distinct projects contribute to the overall research goal
- The NEVA project estimates costs and benefits from high PEV market growth
- The EVI-Pro model estimates EVSE requirements based upon multiple PEV types being served by EVSE networks, using detailed travel and demographic data

Technical Accomplishments and Progress

- The NEVA and Massachusetts Case Study results have been published
- The Columbus, National Corridor, and simple assessment tool studies are ongoing
- Stakeholder engagement and feedback has improved analytic focus and results
- EVSE requirement estimates can be explored using a multi-criteria user interface

Collaboration

- Multiple stakeholder groups have contributed to each of the different projects

Proposed Future Research

- EVSE estimates could be improved by linking to more robust PEV adoption tools
- Additional market data will inform representations of consumer behavior

Acronyms

ANL	Argonne National Laboratory
BaSce	Baseline Scenario (vehicle cost and performance estimates from ANL)
BEV	Battery electric vehicle
BLAST-V	Battery Lifetime Analysis and Simulation Tool
EIA	Energy Information Administration
EVI-Pro	Electric Vehicle Infrastructure Projection tool
EVSE	Electric vehicle supply equipment
GHG	Greenhouse gas
NHTS	National Household Travel Survey
NREL	National Renewable Energy Laboratory
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
ReEDS	Renewable Energy Deployment System

References

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