Committee on Energy Resources and the Environment

Electric utilities and the cost of pursuing of new load: what makes these rate-recoverable expenses?

NARUC Summer Policy Summit

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Modeling Framework and Results to Inform Charging Infrastructure Investments

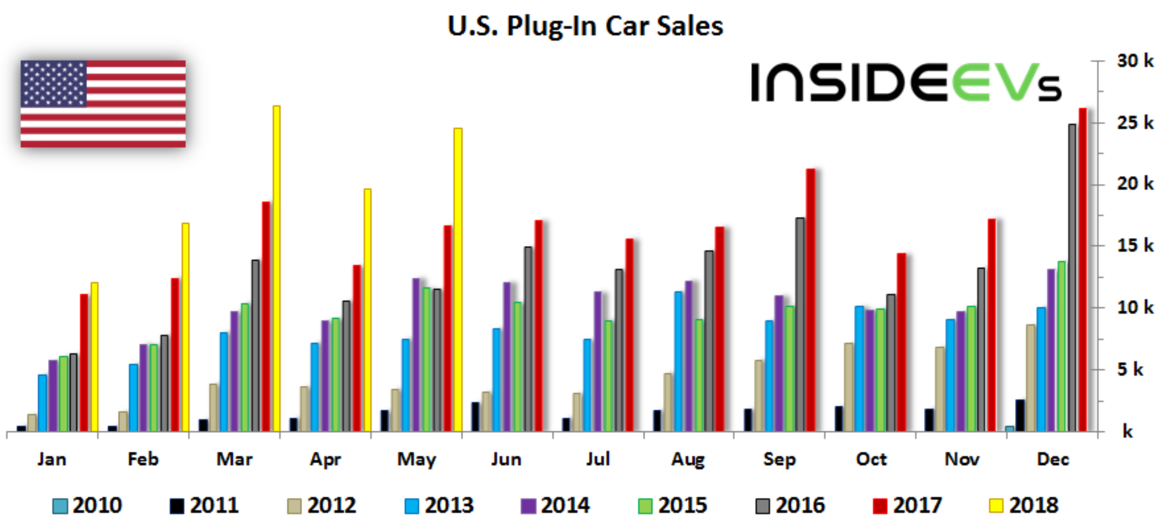
Eric Wood
National Renewable Energy Laboratory

July 2018

NARUC Summer Policy Summit

Methods to Quantify Load Growth from EVs

- Electric vehicles represent a small (but growing) segment of auto sales… *and new load for utilities!*



Methods to Quantify Load Growth from EVs

- Electric vehicles represent a small (but growing) segment of auto sales… *and new load for utilities!*
- If approved/desired, what utility actions can be taken to further encourage sales?
  - Vehicle purchase rebates
  - Charging infrastructure investment
  - Consumer education/awareness

Nissan Leaf Rebate Colorado

Rebates and tax incentives for all-electric car

By: Paul | April 2, 2018 5:13 pm

Maryland's utilities propose spending $104 million on statewide electric-vehicle charging network

California Approves $768 Million for EV Infrastructure

By Brian Orion and Sarah Kozal on June 14, 2018
Posted in California, Climate Change

Methods to Quantify Load Growth from EVs

- Electric vehicles represent a small (but growing) segment of auto sales… *and new load for utilities!*
- If approved/desired, what utility actions can be taken to further encourage sales?
  - Vehicle purchase rebates
  - Charging infrastructure investment
  - Consumer education/awareness
- What methods exist for attributing EV load to each of these actions?
  - Estimating impact on EV sales
  - Estimating load profiles

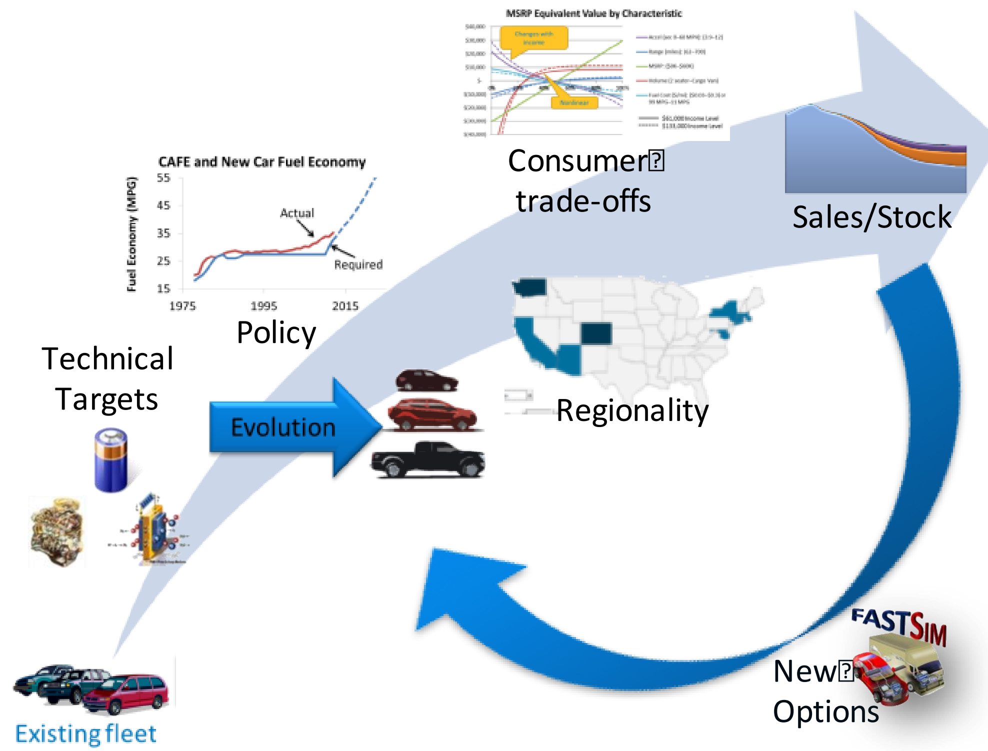
NREL has a model for that!

Automotive Deployment Options Projection Tool (ADOPT)

NREL uses ADOPT (Automotive Deployment Options Projection Tool) to predict consumer demand for different light-duty vehicle types in a given region based on technology evolution, demographic attributes, and policies.

ADOPT

***Can be used to test impact of utility actions on EV sales**



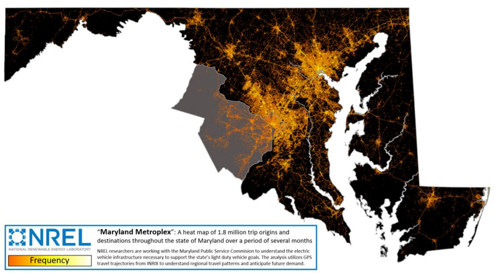
Brooker, A., Gonder, J., Lopp, S., and Ward, J., "ADOPT: A Historically Validated Light Duty Vehicle Consumer ChoiceModel," SAE Technical Paper 2015-01-0974, 2015.

PEV Charging Analysis – NREL Objective

Provide guidance on plug-in electric vehicle (PEV) charging infrastructure to regional/national stakeholders to:

- Reduce range anxiety as a barrier to increased PEV sales
- Ensure effective use of private/public infrastructure investments

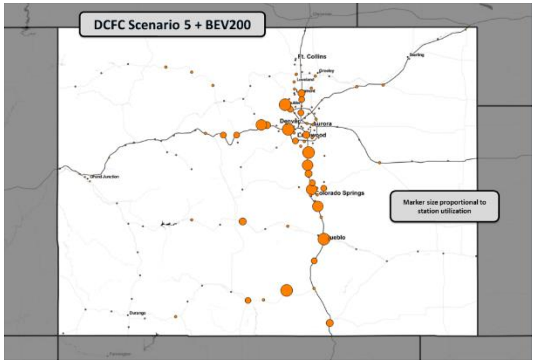
High-resolution travel itineraries → Charging behavior simulation → Infrastructure requirements and load profiles

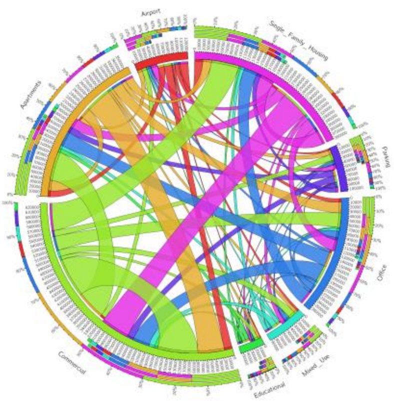


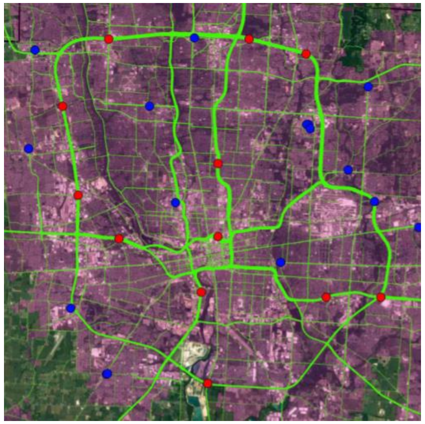
EVI-Pro

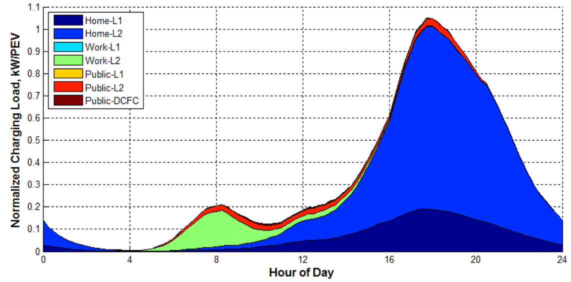
and/or

BLAST-V







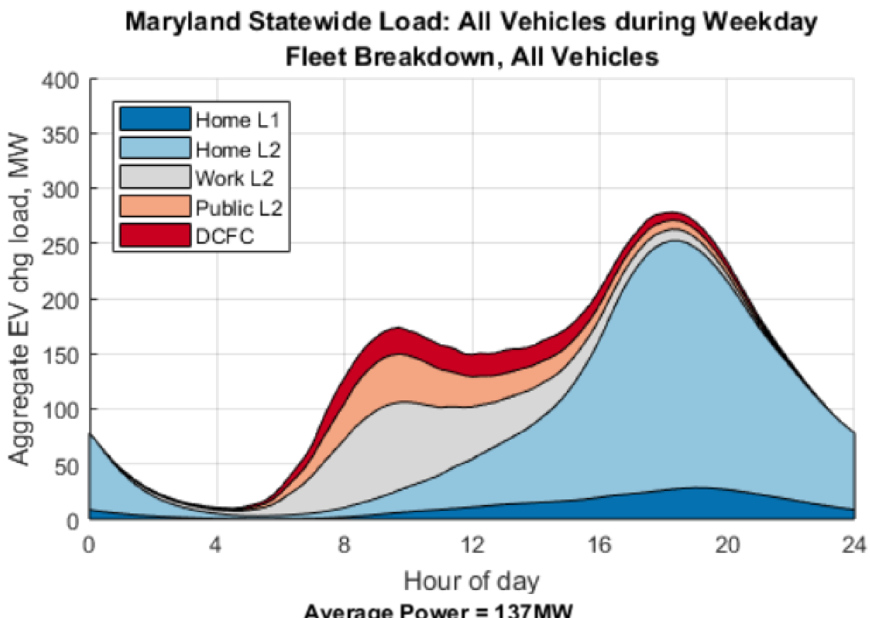


Recent Studies

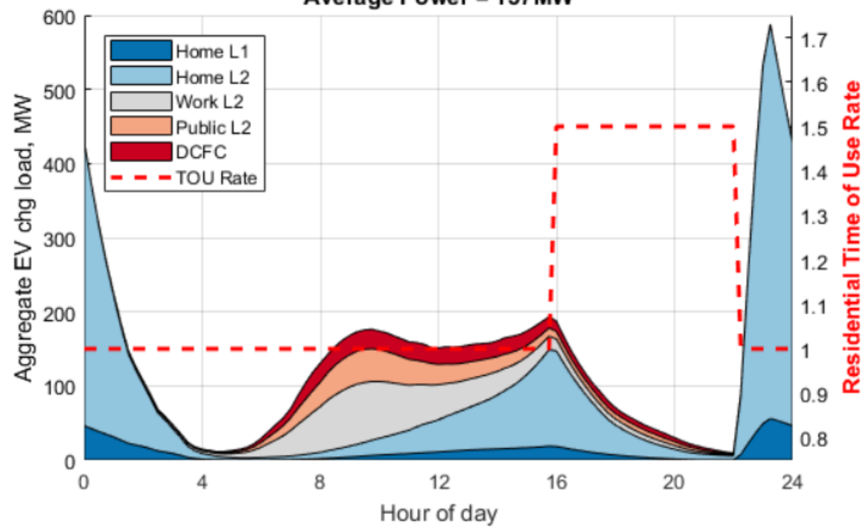
California (2014)
Seattle, WA (2015)
Massachusetts (2017)
Colorado (2017)
National Analysis (2017)
Columbus, OH (2018)
California (2018)
Maryland (forthcoming)

Time of Use Rates

Unconstrained EV charging loads simulated in EVI-Pro

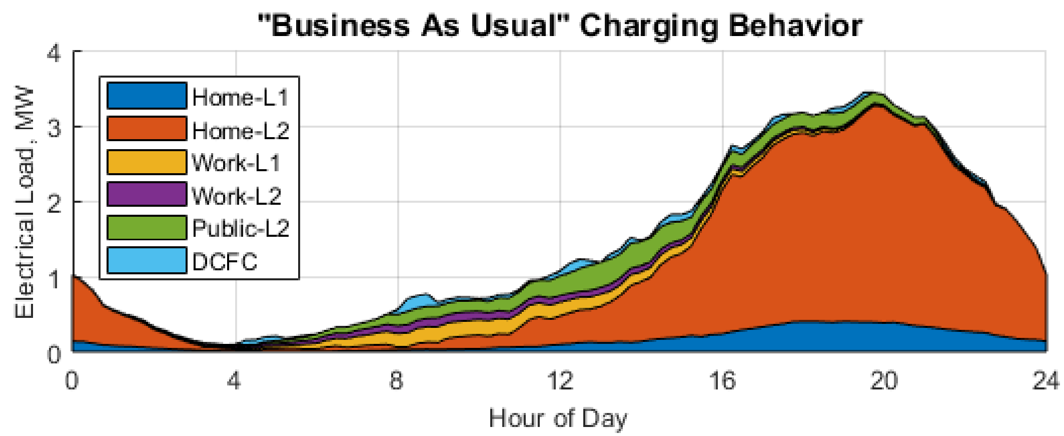


Simulate TOU rates shifting residential load into off-peak hours

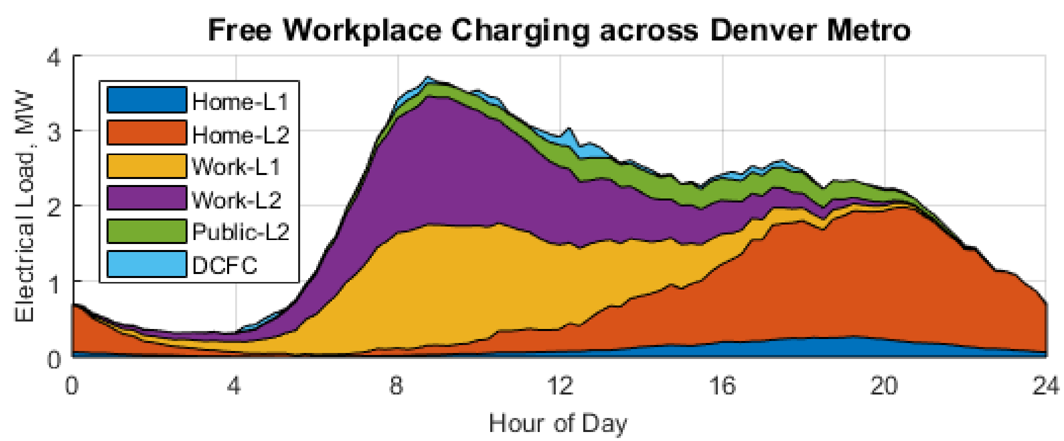


Free Workplace Charging

“Business as usual” home dominant charging behavior



Simulate availability of free workplace charging shifting residential load into AM hours

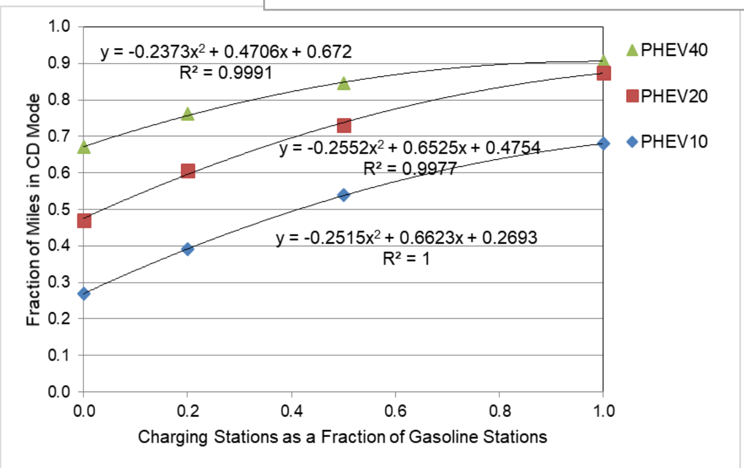


Literature Review & Data Synthesis

Review of studies describing functional relationships, e.g., :

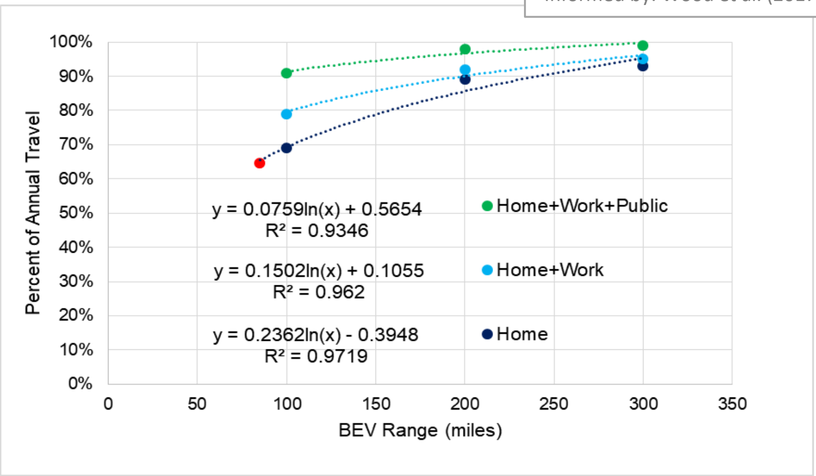
- Chargers coverage – PHEV eVMT %

Informed by: Dong & Lin (2012); Bradley & Davis (2011)

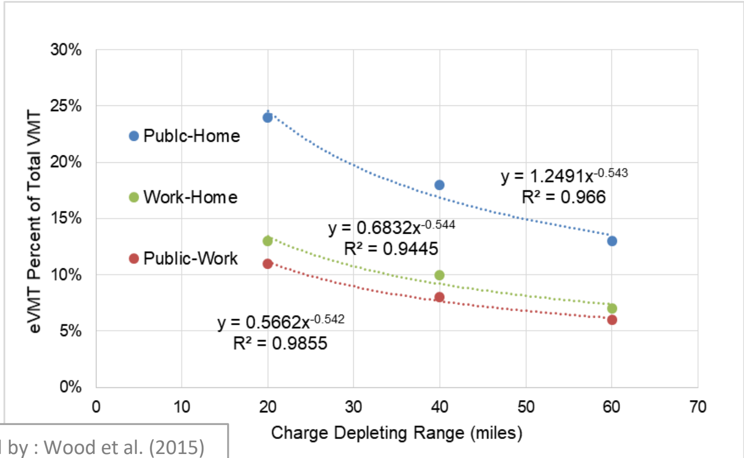


- BEV Range – % of Annual Travel

Informed by: Wood et al. (2017)

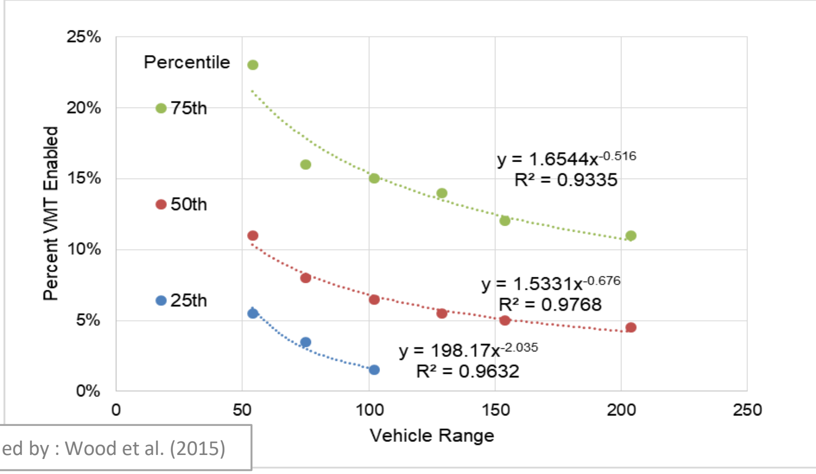


- PHEV range – eVMT %



Informed by : Wood et al. (2015)

- BEV Range – % eVMT enabled by DCFC

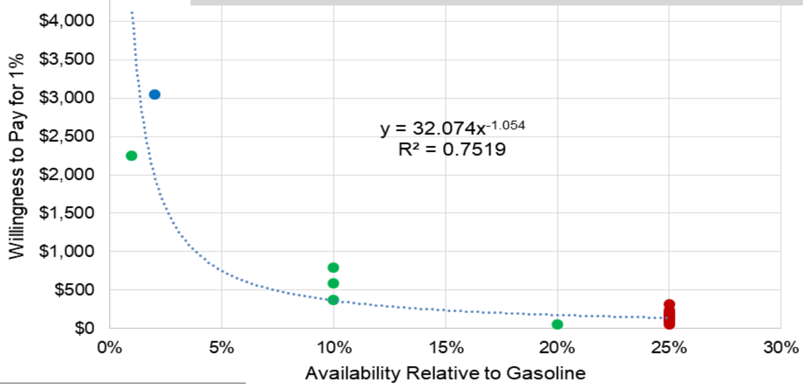


Informed by : Wood et al. (2015)

WTP for Electrified Miles – Review & Synthesis

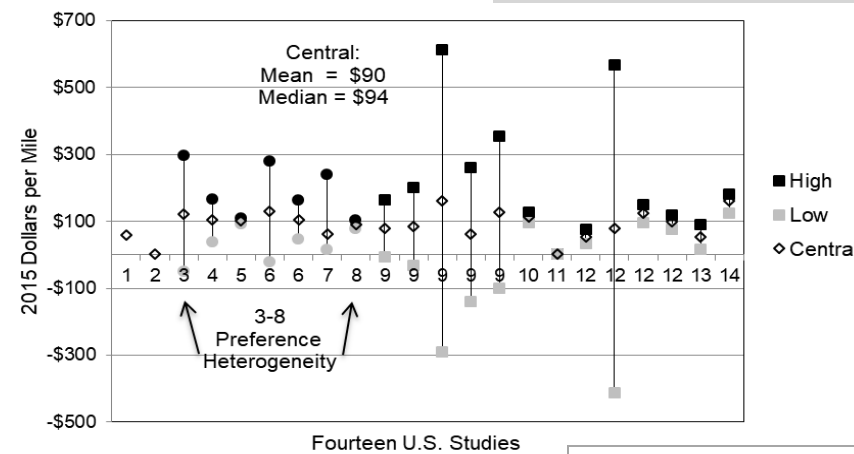
Willingness to pay for infrastructure & electrified mileage relationships

WTP decreases with the inverse of the number of stations



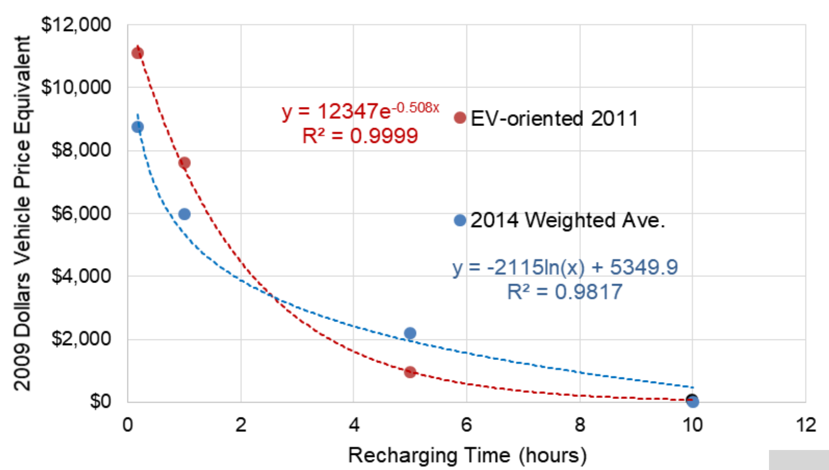
Informed by: Melaina et al. (2013)

WTP $ ranges per mile



Informed by: Greene et al. (2017)

Informed by: Hidrue et al. (2011); Parson et al. (2014)



Present value of reduced recharging time

Summary

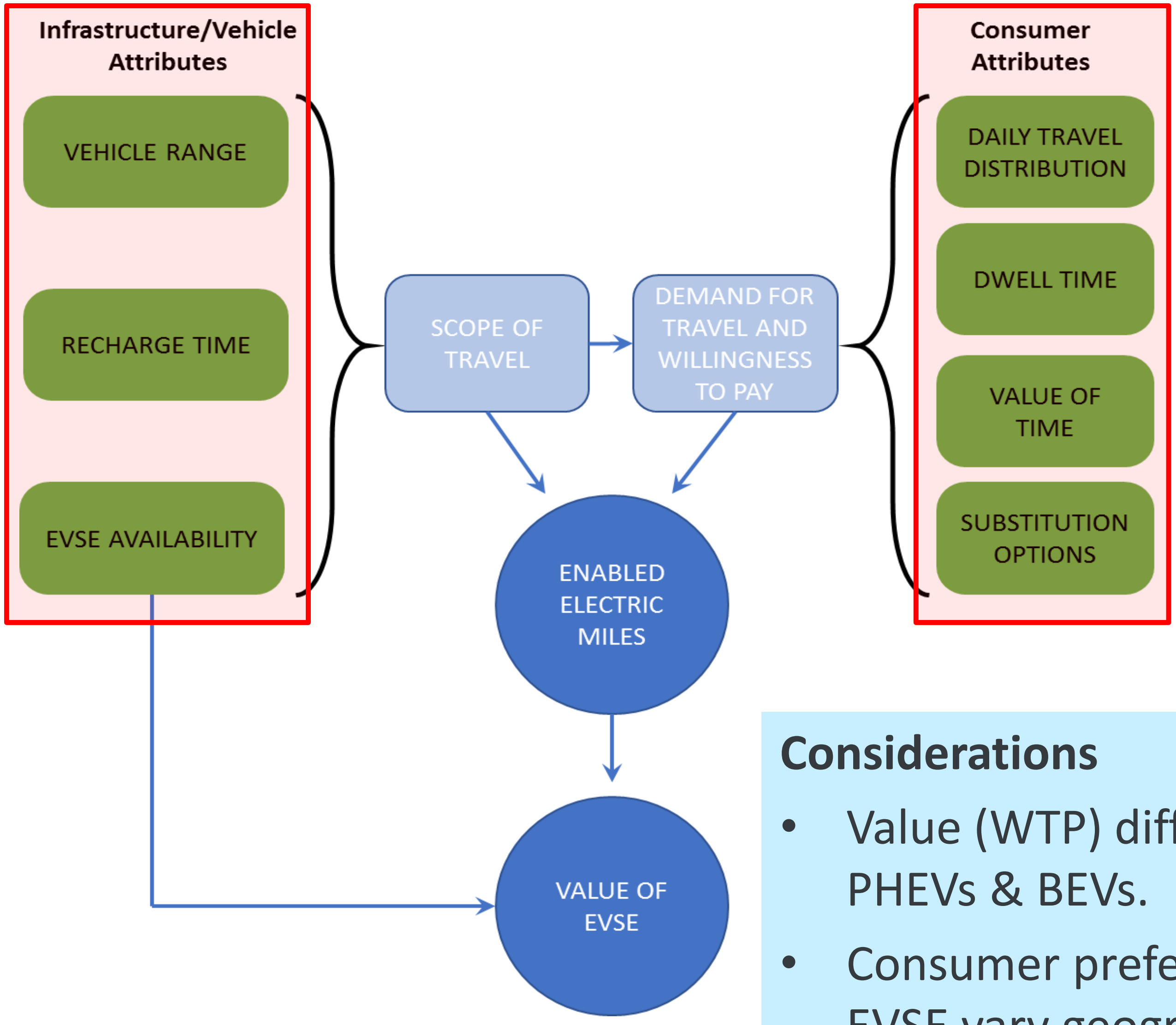
- Sophisticated, well-calibrated models exist for quantifying impacts of vehicle purchase incentives and infrastructure investment on electric vehicle sales and consumer charging behavior

- These models can be used by regulators to estimate the effectiveness of proposed utility actions towards the goal of increasing electrical load across individual service territories

Thanks! Questions?

This work was funded by the US Department of Energy Vehicle Technologies Office, the California Energy Commission, and Potomac Electric Power Company

Factors Affecting Consumer WTP for EVSE



Considerations

- Value (WTP) differs for PHEVs & BEVs.
- Consumer preferences for EVSE vary geographically.

PHEV Value of EVSE

PHEV WTP (at location j and vehicle i) **for EVSE** is represented as the value of **energy savings from additional miles conducted in charge-depleting mode**:

$$WTP_{ij} = \underbrace{\left[f(I_j, R_i) - f(0, R_i)\right]}_{\text{fraction of charge-depleting miles when infrastructure } I \text{ is and is not available}} \overbrace{M_{ij}}^{\text{annual VMT}} \underbrace{\left(p_{jG}e_{iGs} - \left(p_{jG}e_{iGd} + p_{jE}e_{iEd}\right)\right)}_{\text{fuel savings per mile in charge depleting versus charge sustaining mode}} \overbrace{D_{ij}}^{\text{discounted lifetime value}}$$

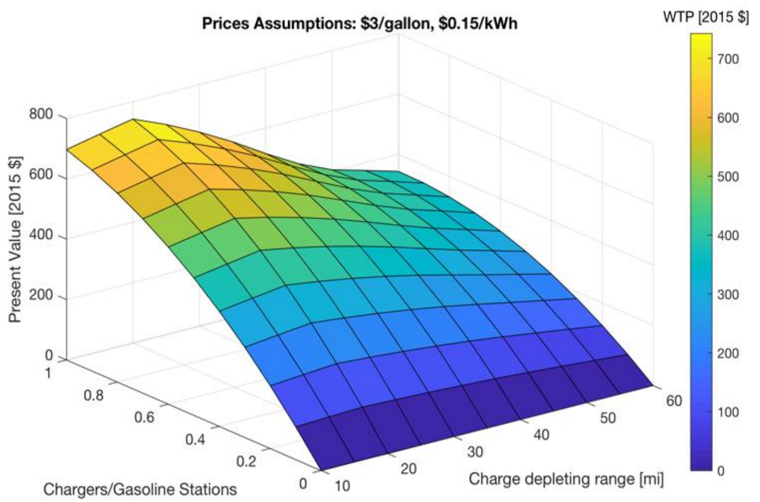


Figure:
PHEV drivers WTP for EVSE infrastructure as a function of range assuming $3/gal for gasoline and $0.15/kWh for electricity

Observations

- WTP ↑ at a decreasing rate when EVSE ↑
- WTP ↓ as when electric range ↑
- WTP max at AER 20 due to energy consumption rates assumed

BEV Intra-Regional Value of EVSE

The contribution of EVSE to the value (utility) of a **BEV** is represented as the **value of added miles**, as for PHEVs, and additionally depends on the **value of an enabled mile, v, and the value, w, of reduced time to access a charger**:

$$WTP = \left[\left(a_0 + a_1 ln\left(\frac{I_j}{X_j}\right)\right)\left(\frac{b_0}{R_i^{b_1}}\right) M_j \underbrace{\left(v_j - \left(w_j K (f_0^{a} - f^{a_2}) \frac{1}{R_i} \right)\right)}_{\text{value per mile of additional enabled travel minus time cost of accessing EVSE}} \right] D_j$$

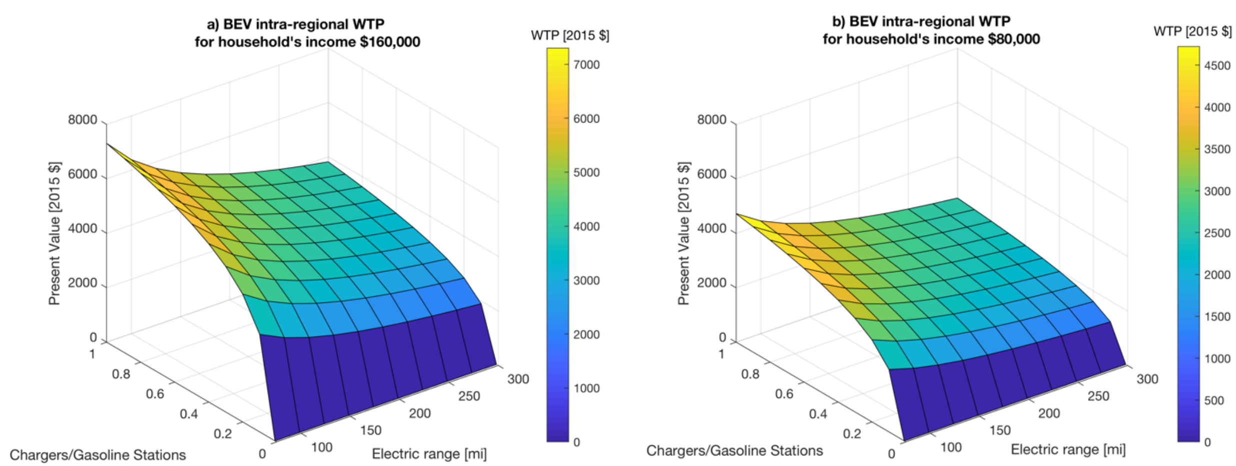


Figure:
BEV WTP for EVSE infrastructure as a function of range

Observations

- WTP ↑ rapidly at first with ↑ EVSE, then diminishing returns
- WTP ↓ as when electric range ↑

BEV Inter-Regional Value of EVSE (DCFC)

The contribution of EVSE, here assumed to be DCFC only, to the value (utility) of a BEV is represented as the **value of added miles**, here assumed :

$$WTP = \left[\left(a_0 + a_1 ln(I_j)\right)\left(\frac{b_0}{R_i^{b_1}}\right) M_j \left(v_j - \left(w_j K(f_0^a - f^{a_2}) \frac{1}{R_i}\right)\right) - \underbrace{C(d_j, I_j, R_i, e_i)}_{\text{time cost of DCFC recharging BEV}} \right] D_j$$

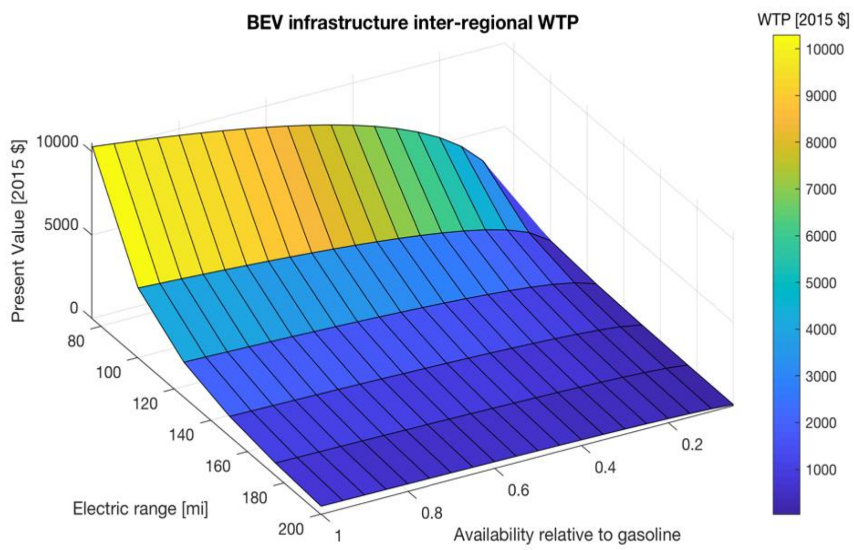
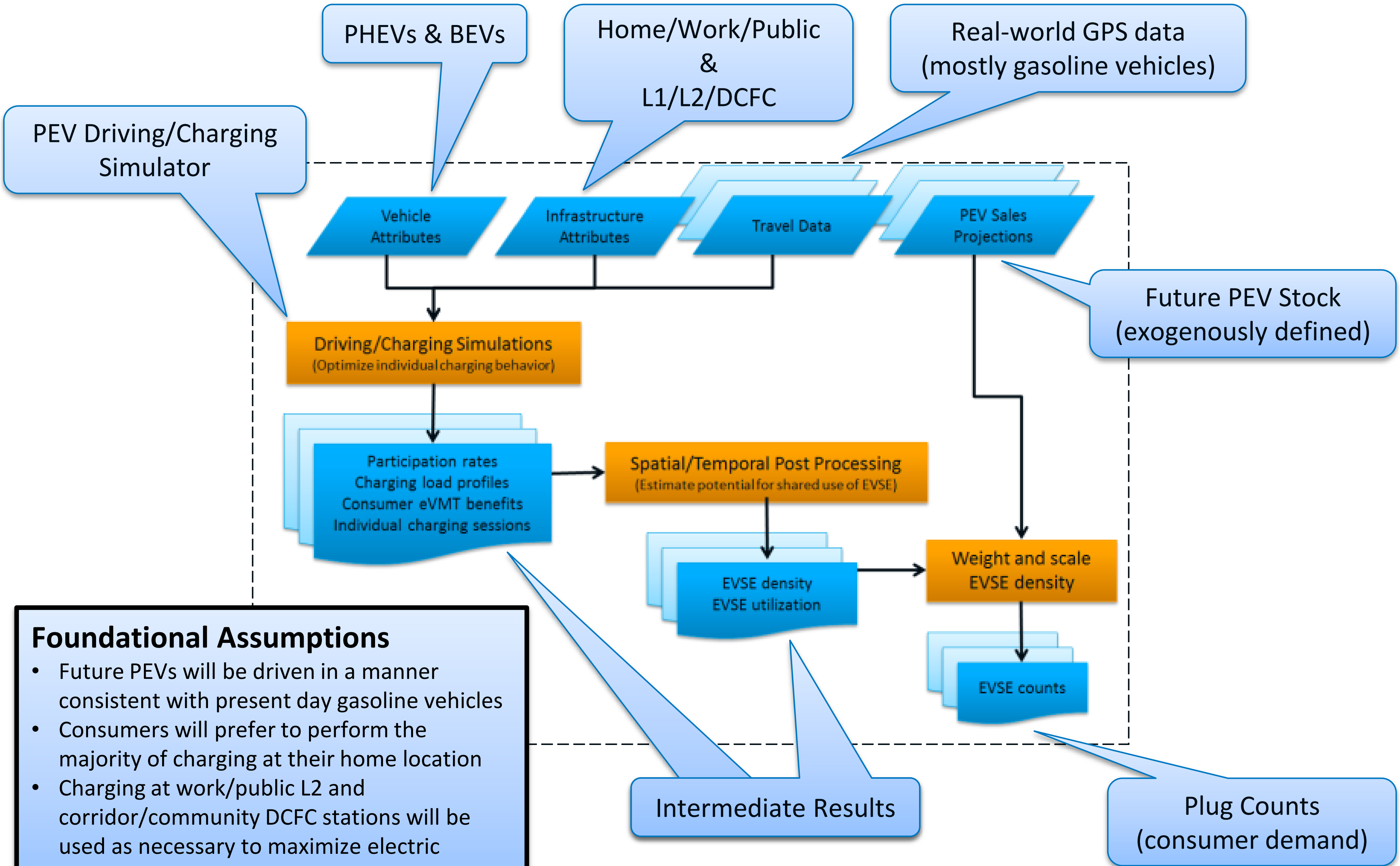


Figure:
BEV WTP for EVSE infrastructure as a function of range assuming a value of $0.35 per enabled mile

Observations

- WTP ↑ at a decreasing rate as EVSE ↑
- WTP ↓ as when electric range ↑

Electric Vehicle Infrastructure Projection Tool (EVI-Pro)



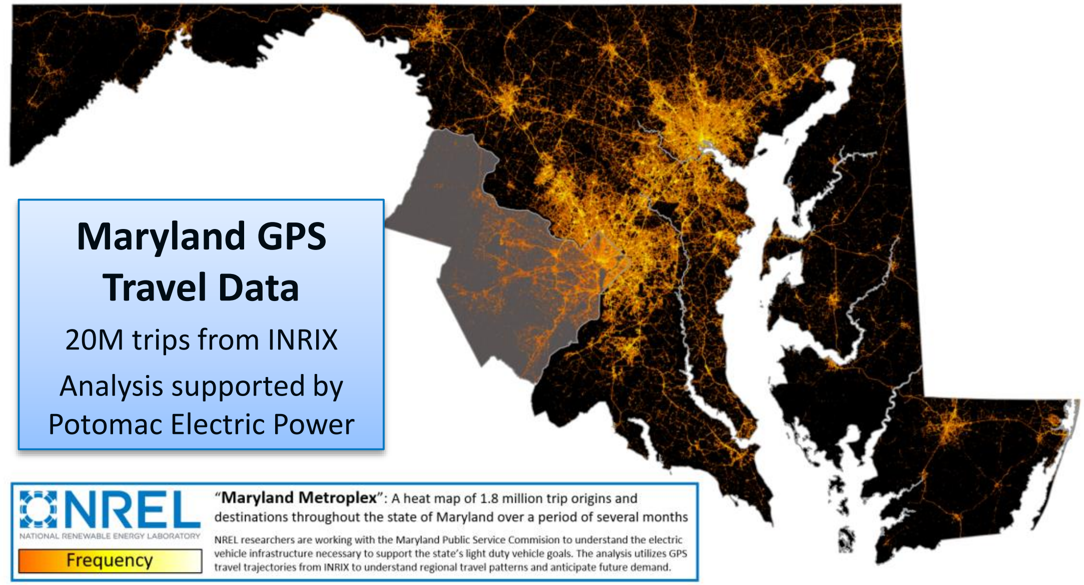
Foundational Assumptions

- Future PEVs will be driven in a manner consistent with present day gasoline vehicles
- Consumers will prefer to perform the majority of charging at their home location
- Charging at work/public L2 and corridor/community DCFC stations will be used as necessary to maximize electric vehicle miles traveled (eVMT)

Consumer Travel Data

One of the fundamental inputs to EVI-Pro is geographically resolved, real-world travel data from the area of interest.

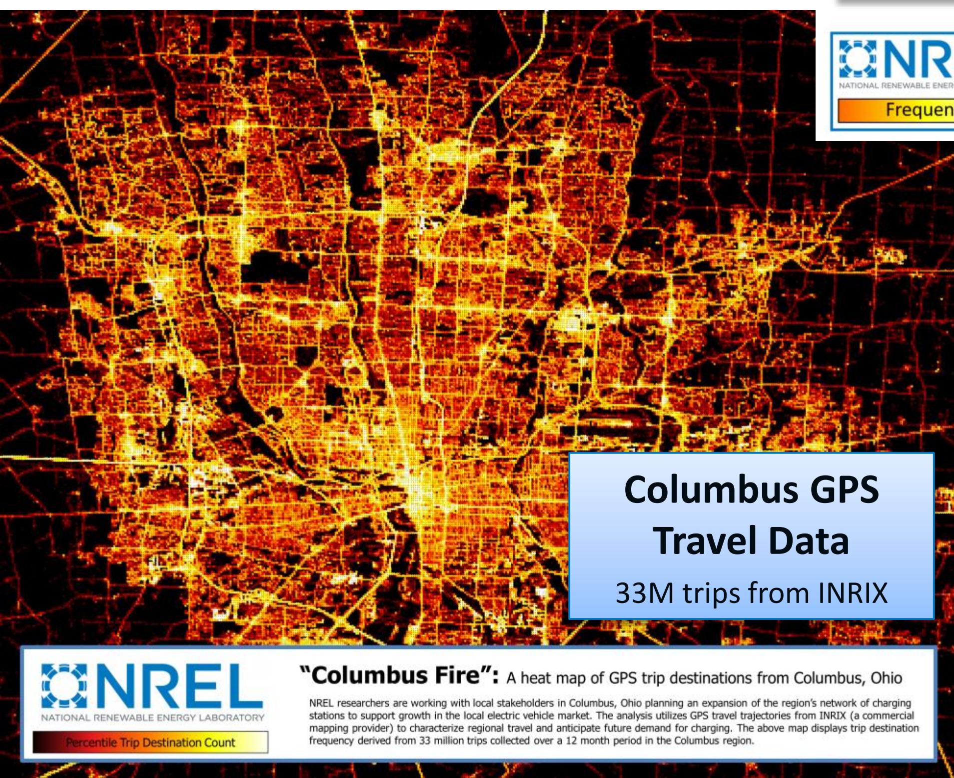
NREL has acquired numerous travel data sets for use in simulating consumer charging requirements by power level, location, and time of day.



Maryland GPS Travel Data

20M trips from INRIX

Analysis supported by Potomac Electric Power



Columbus GPS Travel Data

33M trips from INRIX

National Long Distance Travel Data

9M unique origin-destination (O/D) pairs from FHWA Traveler Analysis Framework

Statewide Assessments in Massachusetts, Maryland, California, Colorado

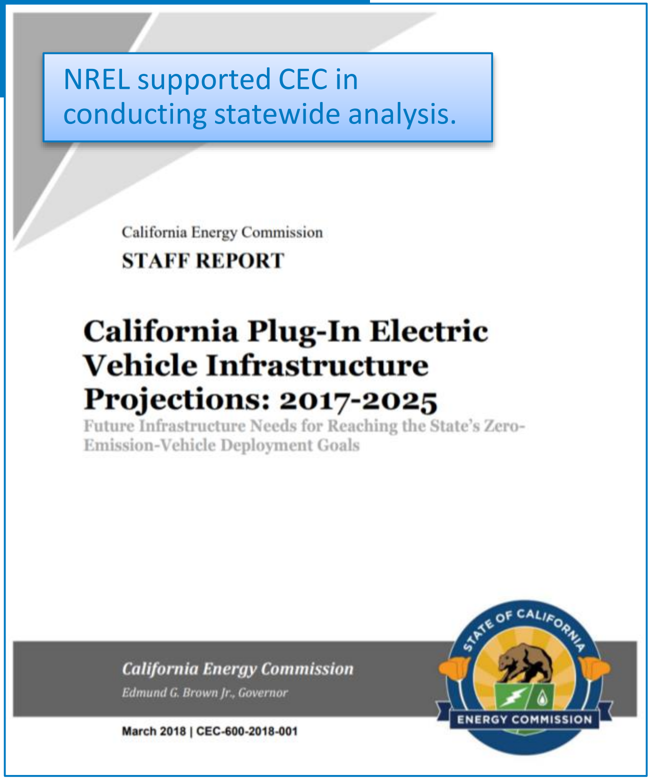
Objective: To provide guidance on PEV charging infrastructure requirements to regional stakeholders.

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

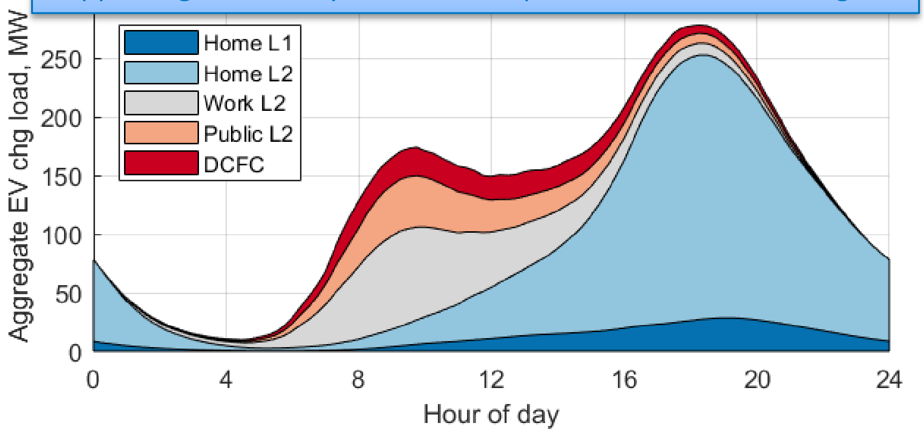
Significance & Impact

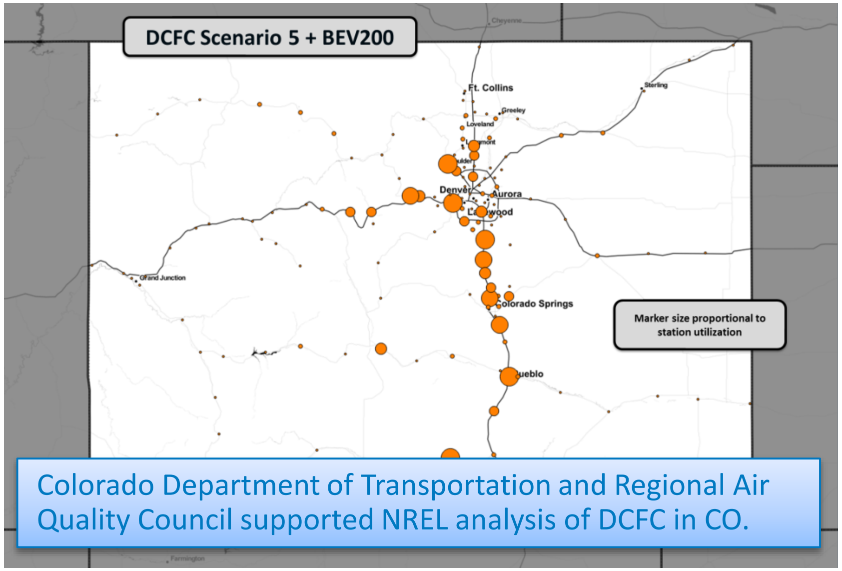
- State agencies in MA, MD, CA, and CO are using demand projections from EVI-Pro to assist in planning statewide EVSE growth supporting PEVs.
- Related organizations have inquired on the potential to run similar analysis in additional states.

NREL supported CEC in conducting statewide analysis.



Potomac Electric and Maryland Public Service Commission supporting NREL analysis of EVSE requirements to meet ZEV goal.





Colorado Department of Transportation and Regional Air Quality Council supported NREL analysis of DCFC in CO.

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Electric Vehicle Cost-Benefit Analysis
The Maryland Example

NARUC 2018 Summer Policy Summit

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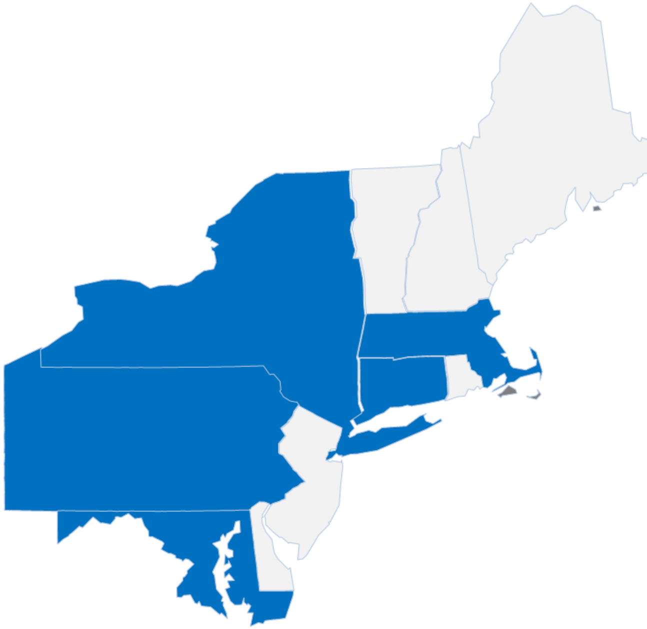
MJB & A

What We Did

Estimated state-wide *net benefits* of high levels of plug-in vehicle (PEV) penetration between 2030 and 2050:

- PEV owner vehicle operating cost savings
- Utility customer savings on electric bills
- Societal benefits from GHG reductions



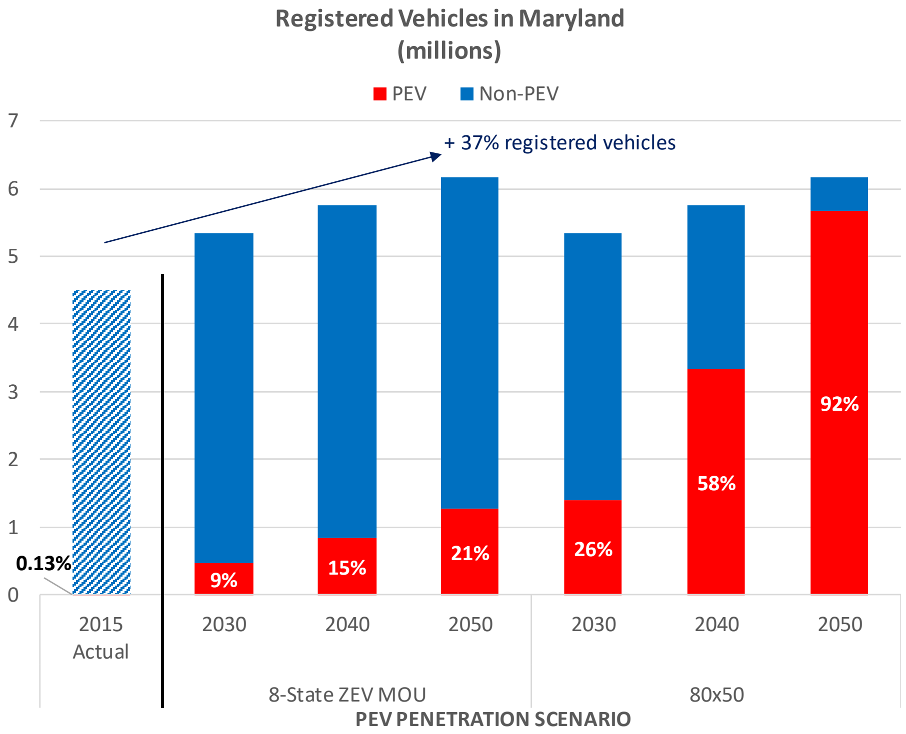
States include CT, MA, MD, NY, PA

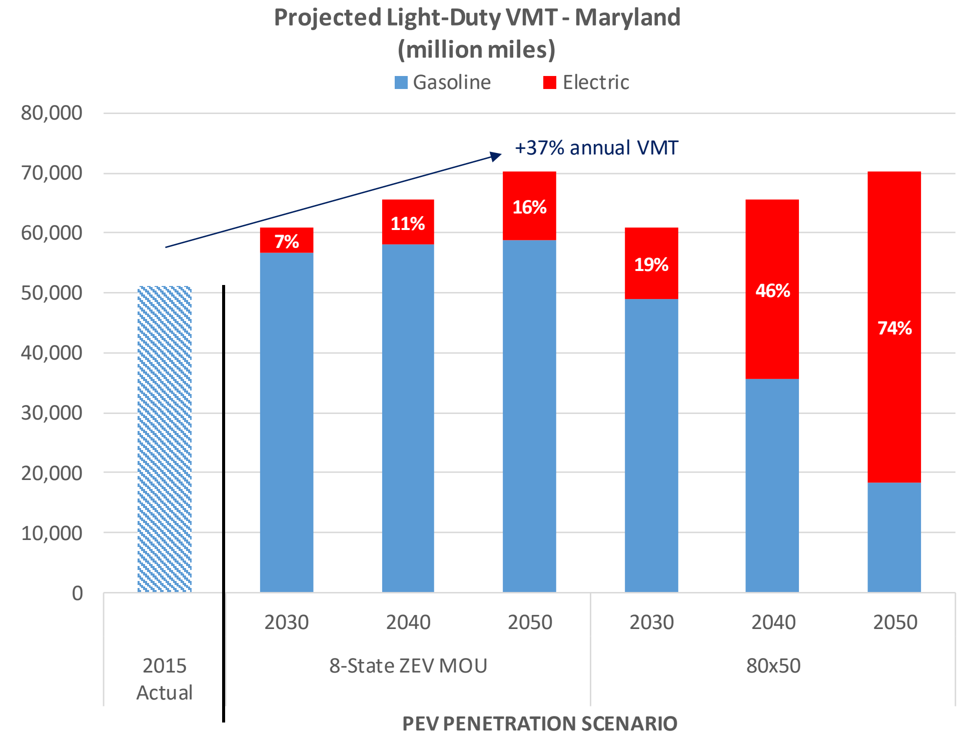
Scenarios bracket short- and long-term state goals for PEV penetration and GHG reduction:

- 8-state ZEV MOU
- Economy-wide GHG reduction goals through 2050

State-specific analyses that account for differences in vehicle fleet, vehicle usage, energy costs, and grid characteristics

PEV penetration scenarios bracket short & long term ZEV and GHG reduction goals





- Current penetration is ~0.13%; under the ZEV MOU commitment, PEV penetration would need to be 6% - 7.5% in 2025
- Under the ZEV MOU scenario, there would be 1.3 million PEVs in MD in 2050
- For the 80x50 scenario, there would be 6 million PEVs in 2050

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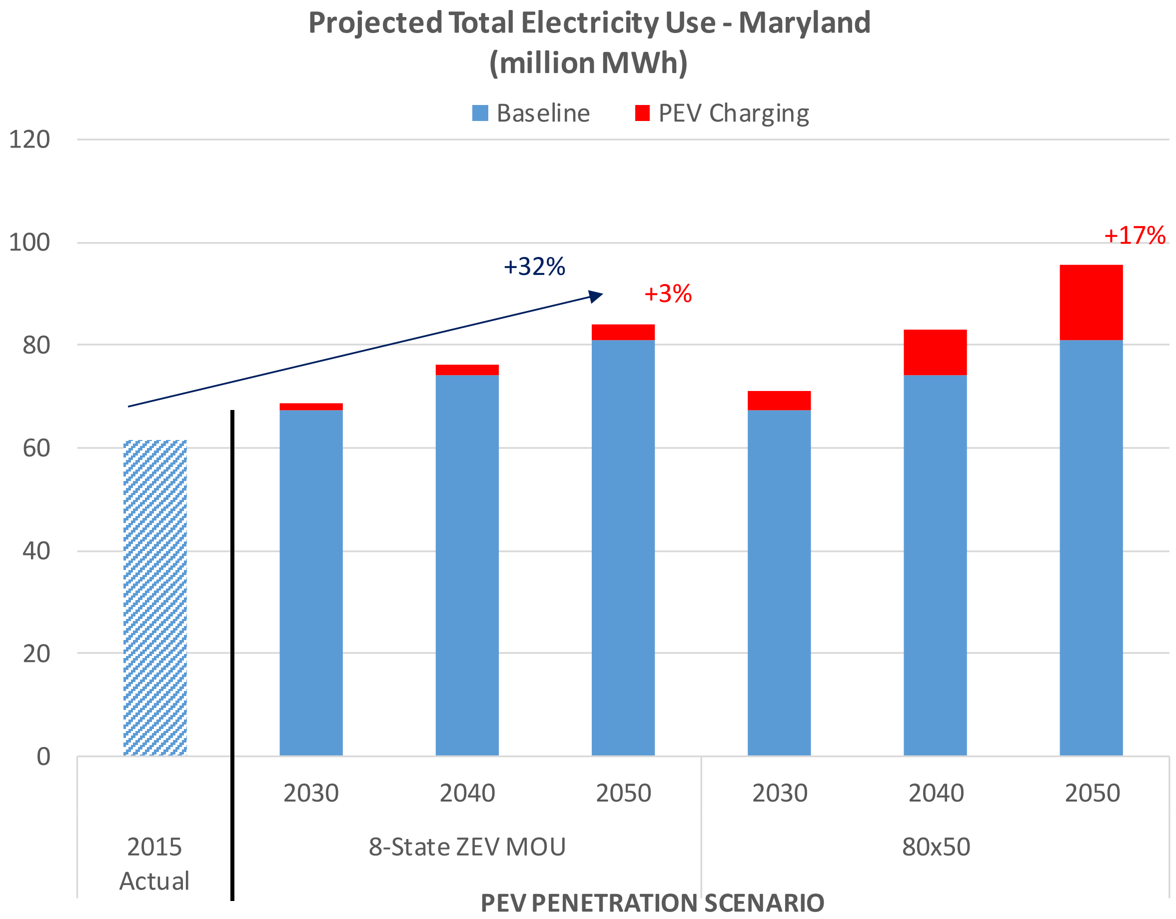
PEV charging could add an additional 17% to electricity use in 2050



- PEV charging would add an additional 3% electricity use by 2050 under the ZEV MOU scenario, and 17% under the 80x50 scenario

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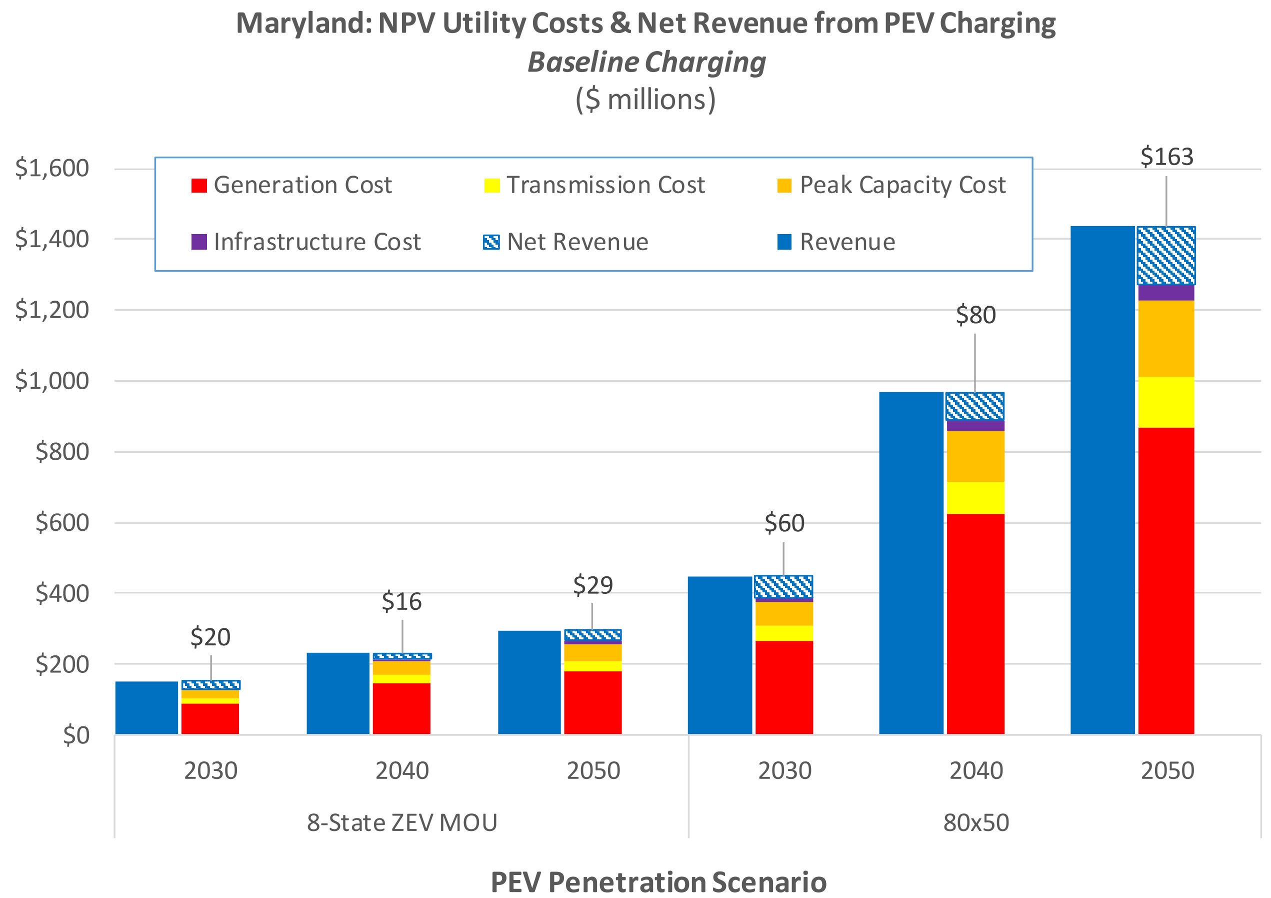
Net revenue from PEV charging could reduce rates by over 3% in 2050



- Under the 80x50 scenario, net revenue from PEV charging could reduce electric rates by 3.5% in 2050 – savings the average MD household $109 per year

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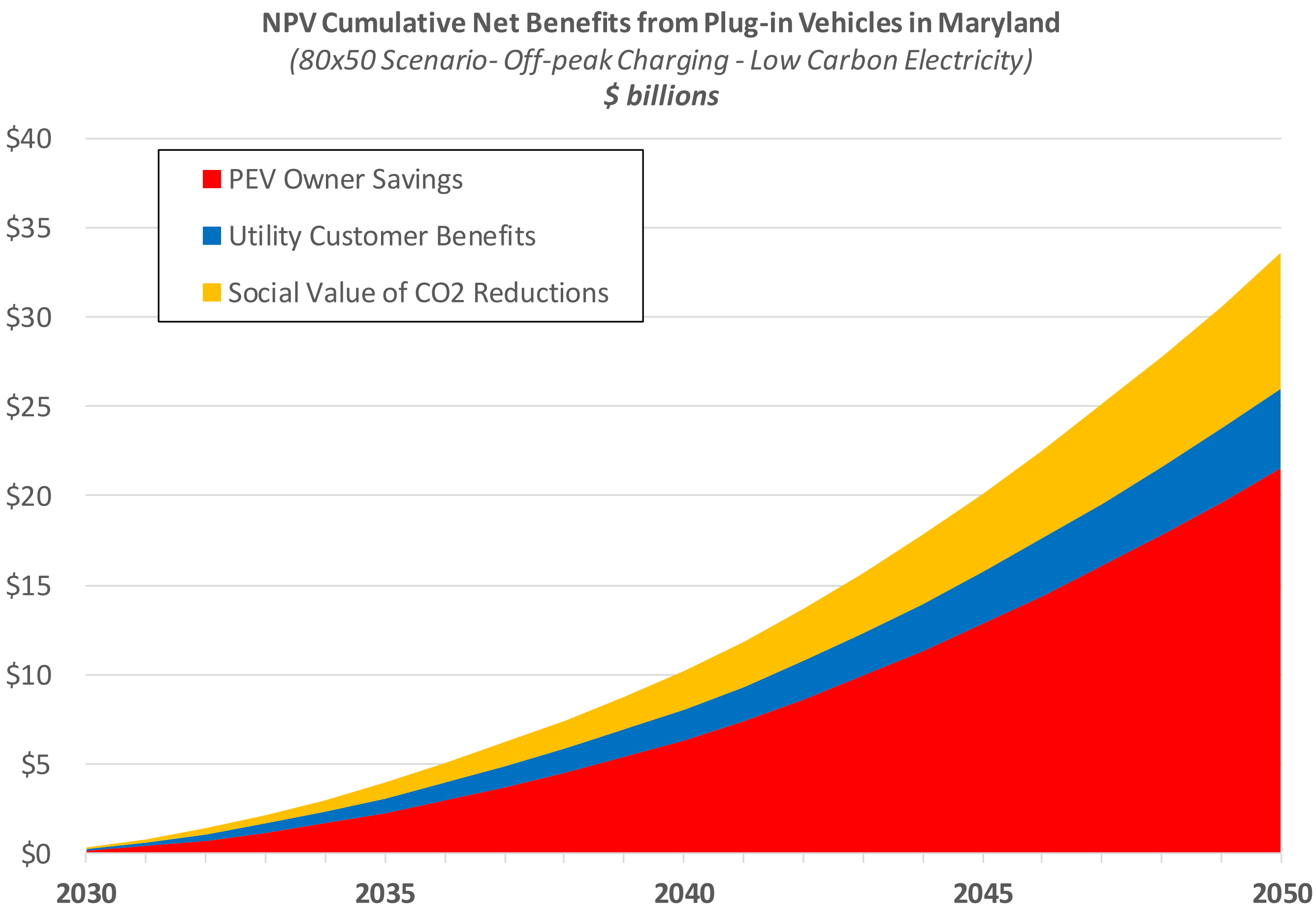
By 2050 cumulative PEV benefits could exceed $33 billion



64% will accrue to PEV owners from savings in vehicle costs

13% will accrue to utility customers from lower electric bills

23% will accrue to society from the value of GHG reductions

NPV based on 3% discount rate

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PEVs provide similar levels of total societal benefits across all states

	NPV ANNUAL BENEFITS - $/PEV							
	2030				2050			
	PEV Owner	Utility Customer	GHG Reduction	TOTAL	PEV Owner	Utility Customer	GHG Reduction	TOTAL
CT	$45	$73	$90	**$208**	$310	$62	$132	**$504**
MA	$14	$90	$91	**$195**	$306	$81	$133	**$520**
MD	$94	$80	$61	**$230**	$338	$58	$124	**$515**
NY	$18	$166	$81	**$265**	$282	$112	$125	**$519**
PA	-$37	$81	$60	**$107**	$210	$60	$96	**$349**

- Utility customer benefits are among the highest in MD due to higher electricity rates and a lower percentage of utility revenue spent on generation & transmission
- PEV owner benefits vary among the states based on differences in electricity costs

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About M.J. Bradley & Associates, LLC

MJB&A, founded in 1994, is a strategic consulting firm focused on energy and environmental issues. The firm includes a multi-disciplinary team of experts with backgrounds in economics, law, engineering, and policy. The company works with private companies, public agencies, and non-profit organizations to understand and evaluate environmental regulations and policy, facilitate multi-stakeholder initiatives, shape business strategies, and deploy clean energy technologies.

About this presentation

This presentation is based on the results of five state-level analyses of plug-in electric vehicle costs and benefits for different states in the Northeast, including Connecticut, Maryland, Massachusetts, New York, and Pennsylvania. These studies were conducted by MJB&A for the Natural Resources Defense Council, to provide input to state policy discussions about actions required to promote further adoption of electric vehicles.

Summary reports for each state can be found here: *http://bit.ly/2kJOfx0*

Current PEVs, State-Level PEV & GHG Goals

Modeled PEV penetration rates bracket these short & long term goals

	2025 PEV Goal *	2050 GHG Goals
CT	150,000	-80% from 2001
MA	300,000	-80% from 1990
MD	300,000	-80% from 2006
NY	850,000	-80% from 1990
PA	None	None
TOT	**1,600,000**	

** 8-state Zero Emission Vehicle Memorandum of Understanding (ZEV MOU). Other states are CA (1.5 million), OR (130,000), RI (40,000) and VT (30,000)*

For each state to meet its ZEV MOU commitments, PEV penetration would need to be 6% - 7.5% in 2025

	LDVs (million)	Registered PEVs (as of 1/16)			
		BEV	PHEV	TOTAL	% of LDV
CT	2.88	1,279	2,090	3,369	0.12%
MA	4.99	2,810	3,523	6,333	0.13%
MD	4.49	2,162	3,741	5,903	0.13%
NY	11.21	6,235	9,717	15,952	0.14%
PA	11.18	2,221	3,887	6,108	0.05%
TOT	**34.75**	**14,707**	**22,958**	**37,665**	**0.11%**

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Projected PEV Purchase Costs

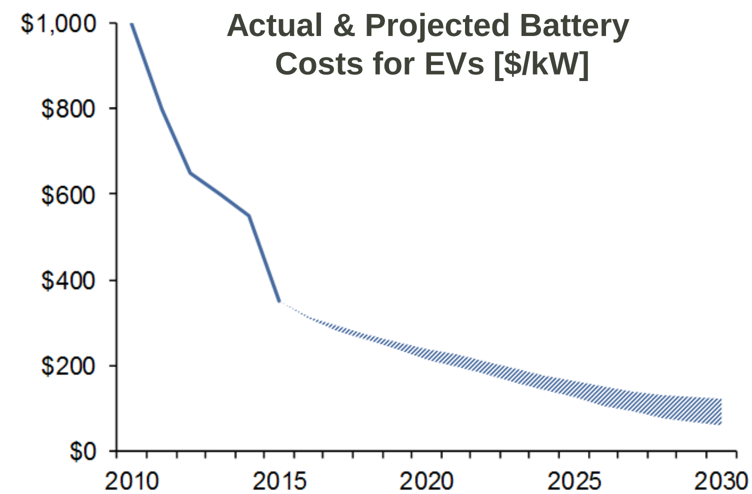
Modeled future PEV purchase costs based on two key parameters

- Battery costs ($/kWh)
- Electric drivetrain costs ($/kW)

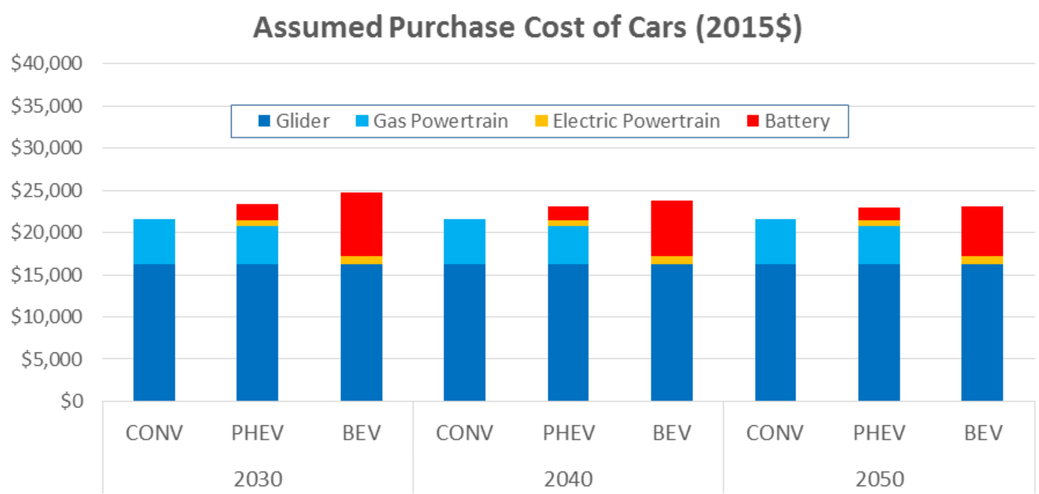
Battery size based on BEV200 and PHEV50

Electric drive train size (kW) based on current PEV models

Future battery & drivetrain costs based on DOE EV Everywhere goals and recent Bloomberg projections



Source: Bloomberg New Energy Finance (2016)



PEVs projected to still be more expensive to buy than gasoline vehicles through 2050, but incremental costs will be more than offset by fuel and maintenance savings

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Major Assumptions

- Baseline is based on current light-duty fleet in each state, and state projections for future vehicle and VMT growth
- Future PEVs assumed to include both plug-in hybrid (PHEV) and battery-electric (BEV) cars and light trucks
  - ✓ PHEV/BEV ratio based on current fleet in each state
  - ✓ PEVs assumed to be mostly cars in 2030, with increasing percentage light trucks in later years, especially under 80x50 scenario
- Future energy costs (gasoline, electricity) based on regional projections from *Energy Information Administration (EIA)*
- Energy use by gasoline cars (baseline) and PEVs consistent with 2015 NRDC/EPRI modeling, and reflect EPA/DOT fuel economy standards (CAFE) through 2025 model year
  - ✓ For PEVs added additional energy to cover winter cabin heating
- PEV GHG emissions based on EIA projections for future grid carbon intensity (baseline), and a "low carbon" scenario in which grid emissions are reduced 80% by 2050
- Evaluated PEV charging load for both "baseline" and "off-peak" charging

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