NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Regional PEV Charging Infrastructure Analysis

Regional Infrastructure Assessment
Analytic Approach and Massachusetts Case Study

Eric Wood and Marc Melaina
National Renewable Energy Laboratory

Aug 15, 2016

Motivation

- The value of PEVs to consumers and fleet operators can be increased with well-planned and cost-effective deployment of charging infrastructure. This is achieved by increasing the number of miles driven electrically and accelerating PEV market penetration, bringing down manufacturing costs and increasing the positive network externalities of charging networks. The complexity and cost of PEV charging infrastructure poses challenges to decision makers, including individuals, communities, and companies considering infrastructure installations such as workplace charging.

- Given the complex issues associated with PEV charging and options in deploying charging infrastructure, EV Everywhere is interested to analyze existing systems, question current practices, and explore and develop scenarios of future charging infrastructure development to provide insight and guidance to national and regional stakeholders. Additional insight is needed on the role of charging infrastructure in accelerating PEV market growth.

- Objective: To provide guidance on PEV charging infrastructure to regional stakeholders through the DOE EV Everywhere Grand Challenge.

Outline

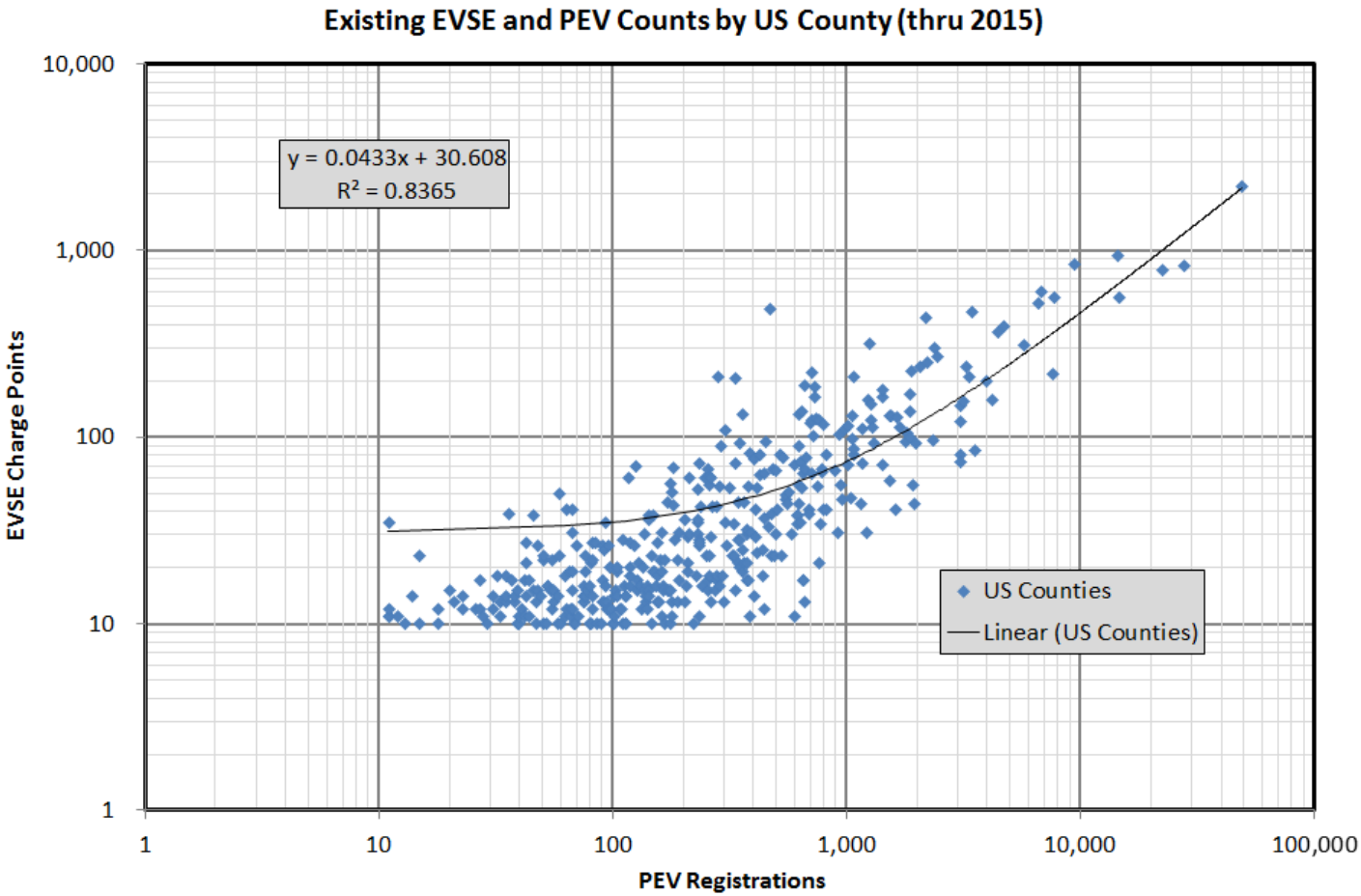
- **Current state of public EVSE networks**
  - Scope: National & Massachusetts
  - Data Source: AFDC Station Locator and IHS Automotive Vehicle Registration Database (previously R.L. Polk)
- **Analytic Approach**
  - EVI-Pro Tool (collaborative development with CEC)
- **Massachusetts Case Study**
  - Multi-state ZEV action plan: 300,000 PEVs in Massachusetts by 2025
  - Apply 2011 MassDOT Travel Survey to EVI-Pro Tool
  - Evaluate a handful of consumer charging behavior scenarios

EVSE: Electric Vehicle Supply Equipment
AFDC: DOE Alternative Fuels Data Center
EVI-Pro: Electric Vehicle Infrastructure Projection Tool
CEC: California Energy Commission
ZEV: Zero emission vehicle
PEV: Plug-in electric vehicle (battery electric and plug-in hybrid electric)
MassDOT: Massachusetts Department of Transportation

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

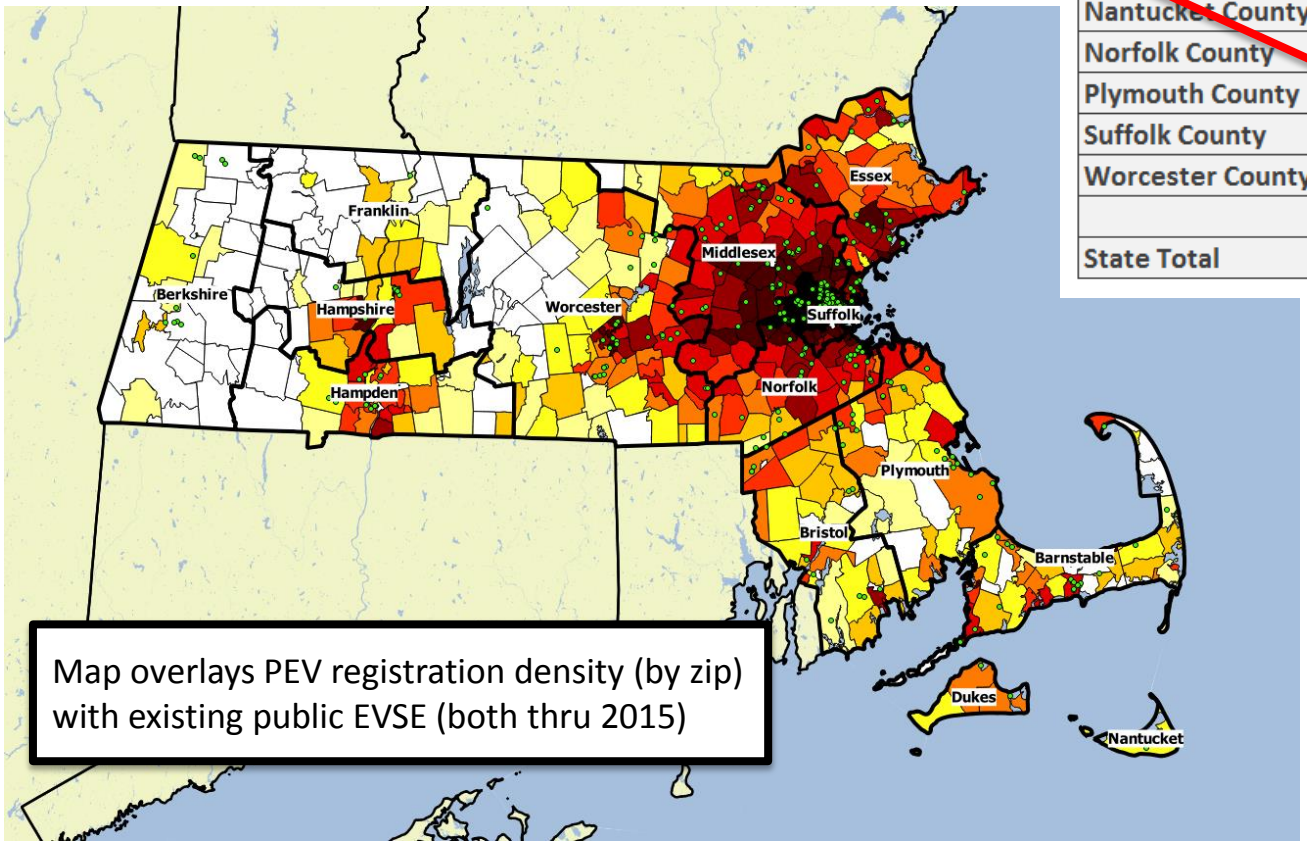
Current state of public EVSE networks

- Vehicle registration and station location data are overlaid to examine correlation
- Linear trend line reveals relatively strong correlation between number of EVSE charge points (plugs) and PEV registrations at the county level (excludes counties with less than 10 charge points or PEVs)
- The average US county currently provides **43 public plugs for every 1000 PEVs**
- Important to acknowledge that causality of this relationship is still under investigation



Massachusetts is currently well above national average in terms of number of charge points per registered PEV

County	Charge Points	PEVs	EVSE per 1000 PEV
Barnstable County	43	181	238
Berkshire County	22	82	268
Bristol County	28	236	119
Dukes County	3	60	50
Essex County	66	657	100
Franklin County	10	86	116
Hampden County	34	213	160
Hampshire County	40	267	150
Middlesex County	300	2,366	127
Nantucket County	10	13	769
Norfolk County	123	759	162
Plymouth County	53	318	167
Suffolk County	189	665	284
Worcester County	75	632	119
State Total	996	6,535	152



Map overlays PEV registration density (by zip) with existing public EVSE (both thru 2015)

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Analytic Approach

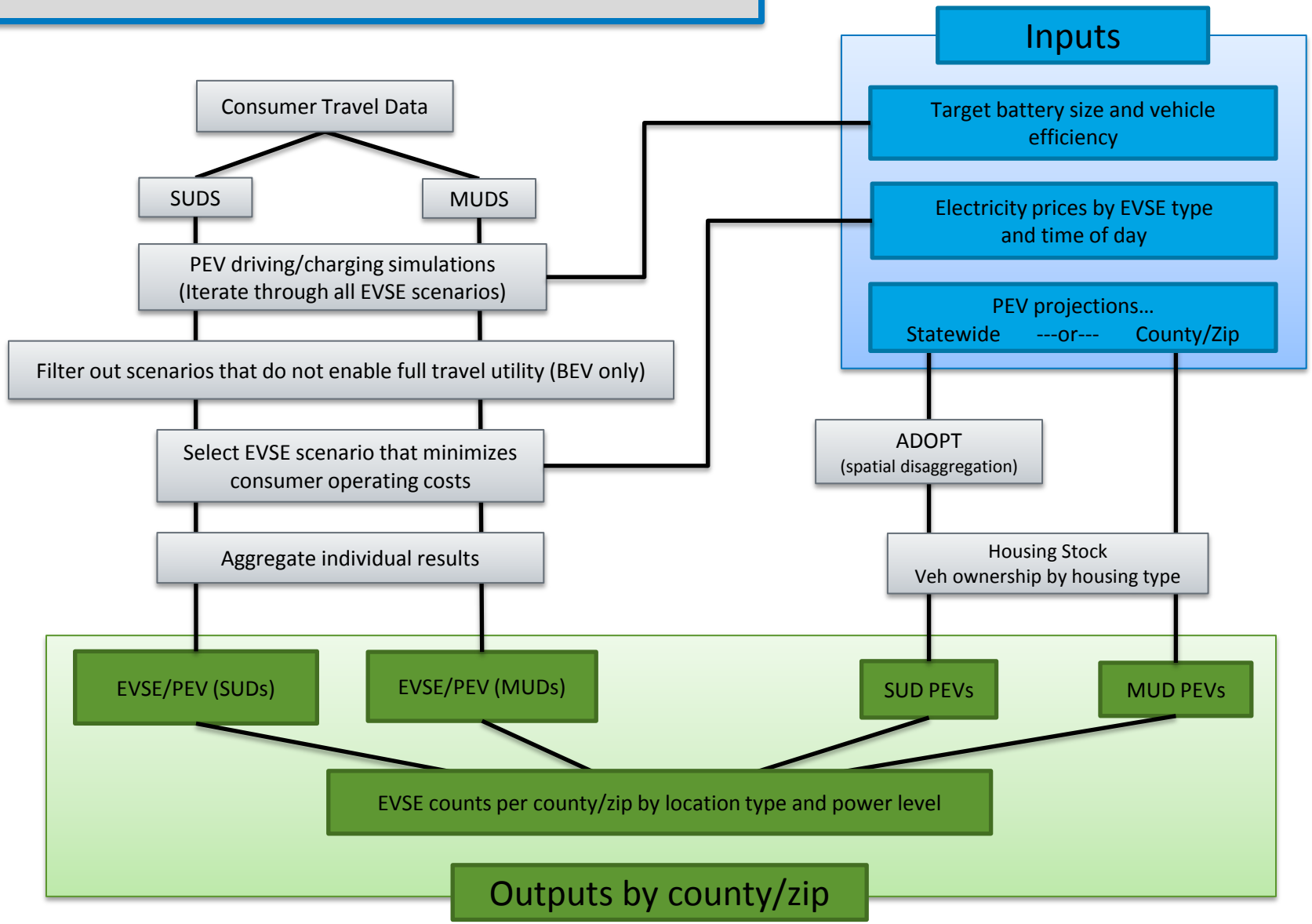
Analytical Approach

- In addition to present day market data on PEV adoption and public EVSE installations, we would like to be able to model future requirements for public EVSE under various PEV adoption scenarios
- In collaboration with the California Energy Commission, NREL is developing the Electric Vehicle Infrastructure Projection Tool (EVI-Pro)
- EVI-Pro utilizes PEV market projections and real-world travel data from mass market consumers to estimate future requirements for home, workplace, and public charging

- **Anticipate spatial/temporal consumer demand for charging**
- **Capture variations with respect to**
  - Residents of single- and multi-unit dwellings
  - Weekday/weekend travel behavior
  - Regional differences in travel behavior and vehicle adoption
- **Fundamental assumption**
  - Consumers prefer to maximize eVMT and minimize operating cost

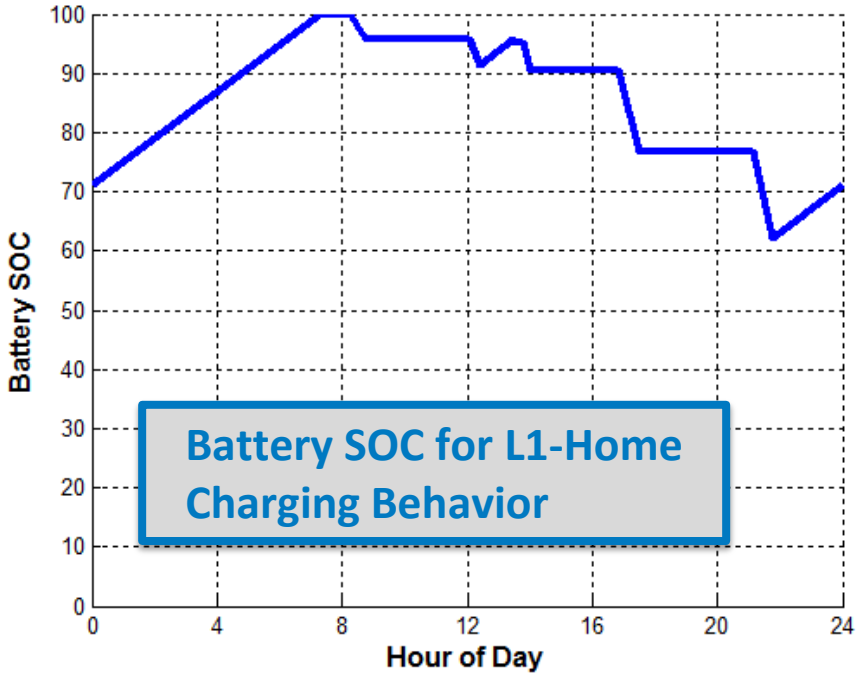
Model Goals

EVI-Pro (model structure)



Simulate Single Travel Profile

Start Time	Miles	Destination	Dwell Hours
8:15 AM	4.3	Work	3.3
12:05 PM	4.3	Home	1.1
1:28 PM	0.6	Public	0.2
1:48 PM	4.5	Work	2.8
4:50 PM	13.8	Public	3.7
9:10 PM	14.6	Home	10.5



Battery SOC for L1-Home Charging Behavior

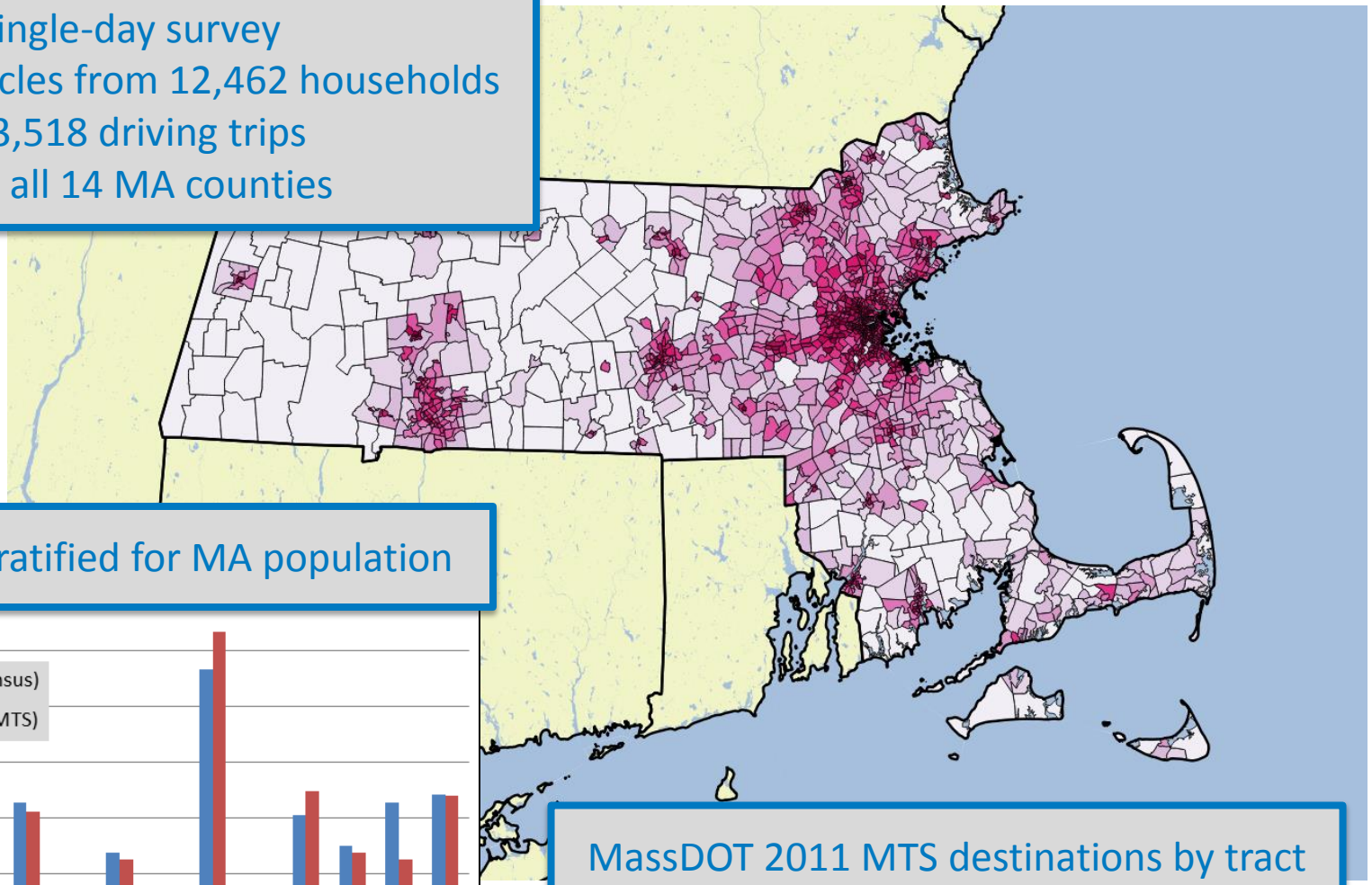
- Simulate travel day in a BEV100
- Iterate through all combinations of charging behavior
- Select charging strategy that meets travel requirements and minimizing charging costs (given specific rate structure)

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Massachusetts Case Study

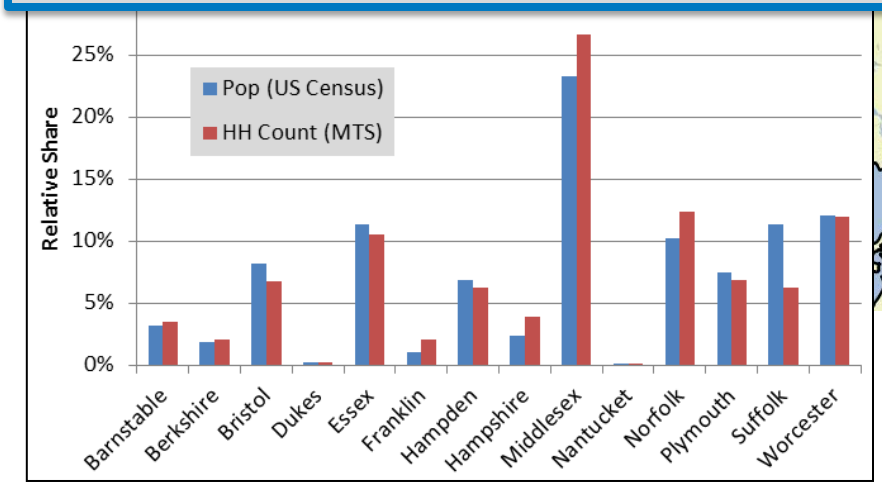
2011 Massachusetts Travel Survey (MassDOT)

- 2011 MTS single-day survey
- 20,177 vehicles from 12,462 households
- Collected 83,518 driving trips
- Coverage in all 14 MA counties



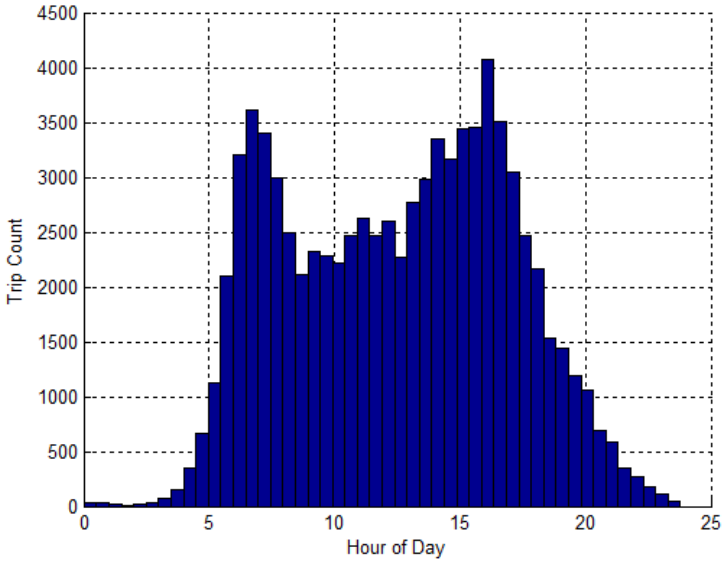
MassDOT 2011 MTS destinations by tract

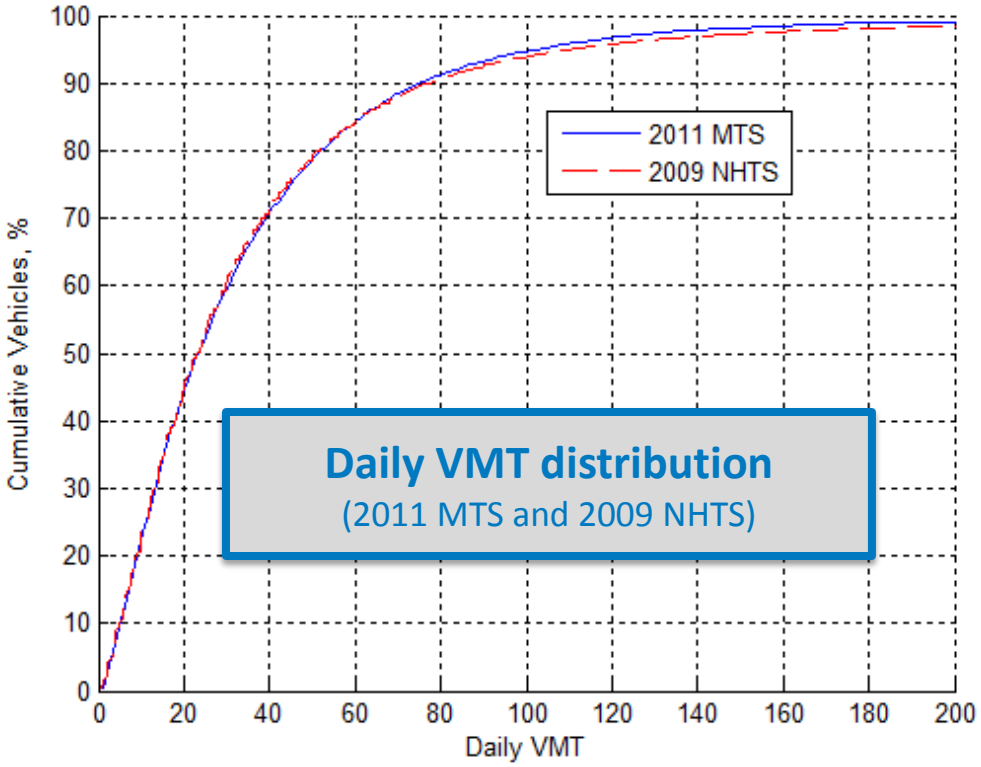
MTS sample stratified for MA population



2011 Massachusetts Travel Survey (MassDOT)

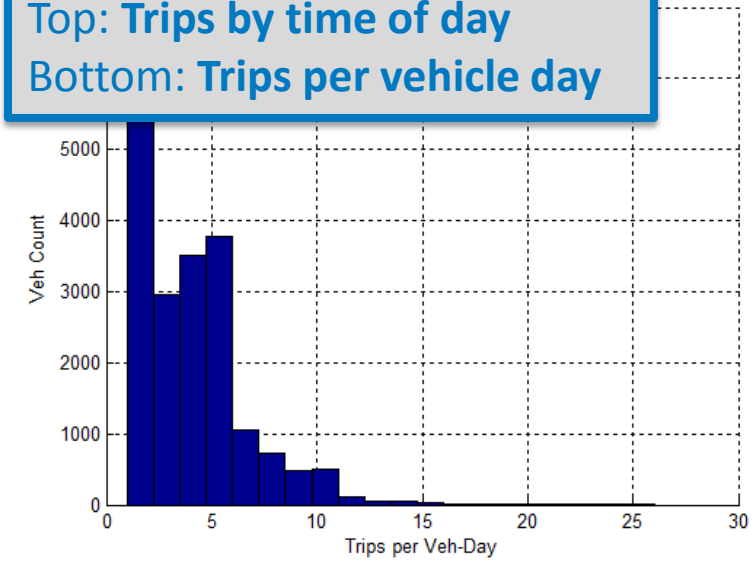
2011 MTS exhibits travel statistics typical of US regional and national surveys





Daily VMT distribution
(2011 MTS and 2009 NHTS)

Top: **Trips by time of day**
Bottom: **Trips per vehicle day**



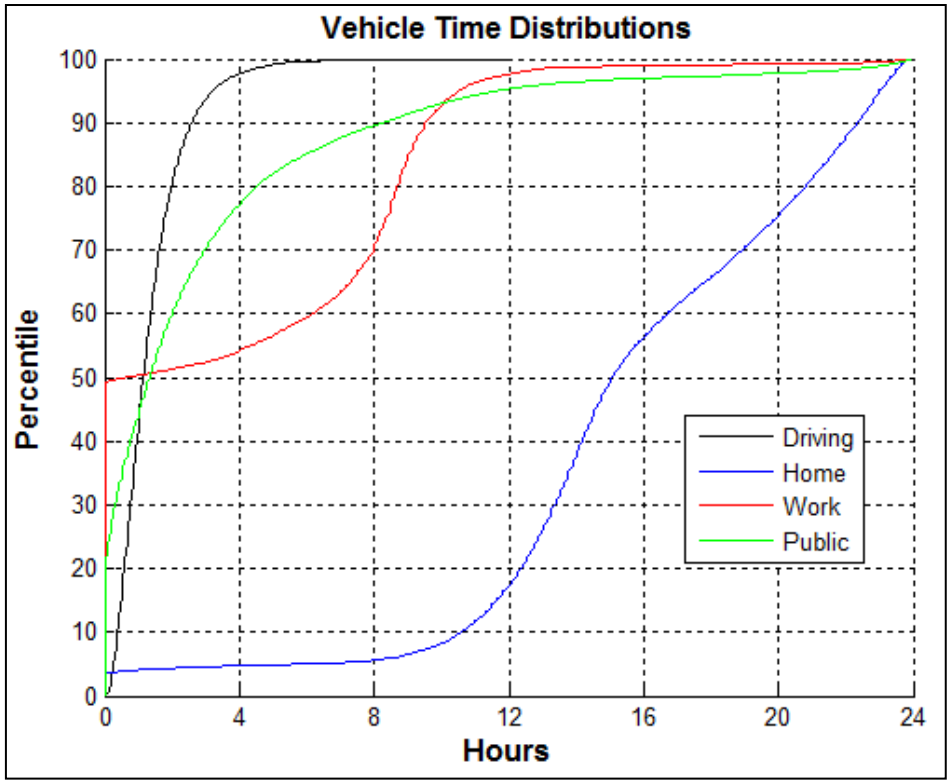
2011 Massachusetts Travel Survey (MassDOT)

Average MTS vehicle spent

- 1.4 hours driving
- 15.6 hours parked at home
- 4.1 hours parked at work (8.4 hours for commuters)
- 3.0 hours parked at public locations

However, not all vehicles are average

- 10% of sample spent >2.5 hours driving
- 6% of sample spent <9 hours at home
- 49% of sample made no work trips
- 10% of sample spend >8 hours at public locations

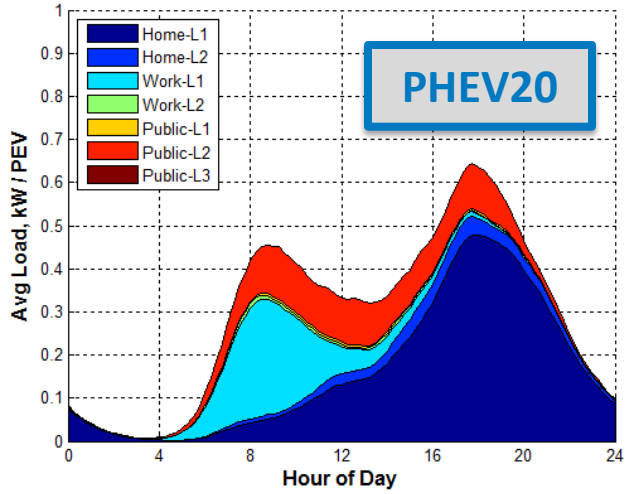


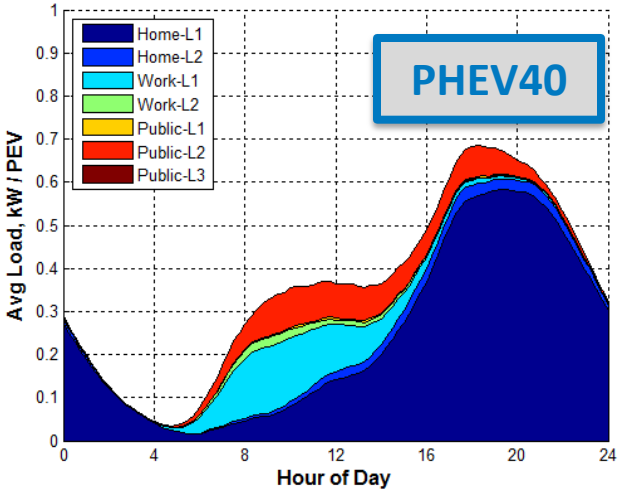
EVI-Pro Simulations

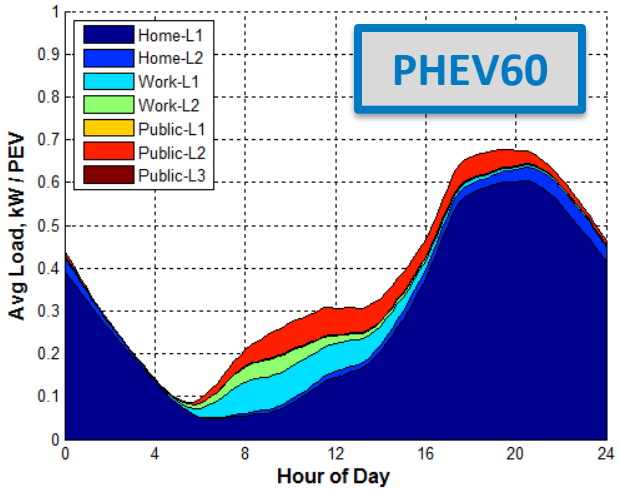
- **Run EVI-Pro using 2011 MTS**
- **Input assumptions:**
  - Consumers have access to and prefer to perform majority of charging at their home location (including residents of multi-unit dwellings)
    - Scenarios including public charging preferences has been run, but are not included in this presentation
  - Equal split between PHEVs and BEVs
    - PHEV20, 40, 60 and BEV100, 200, 300
  - Public infrastructure options:
    - Level 1 (1.4kW); Level 2 (6.2kW); DCFC (50.0kW)

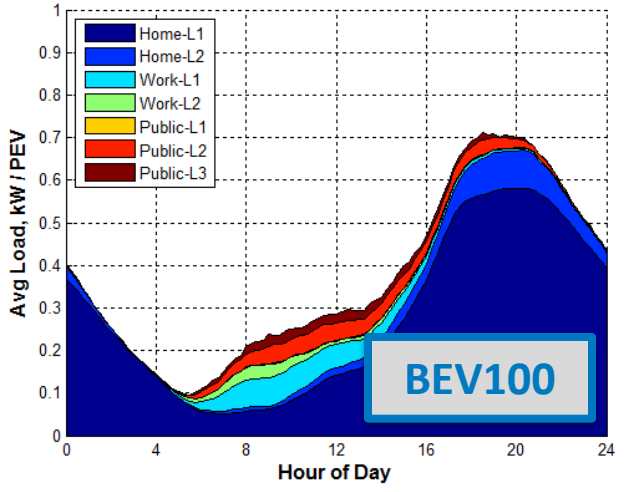
Simulated consumer load profiles by vehicle type

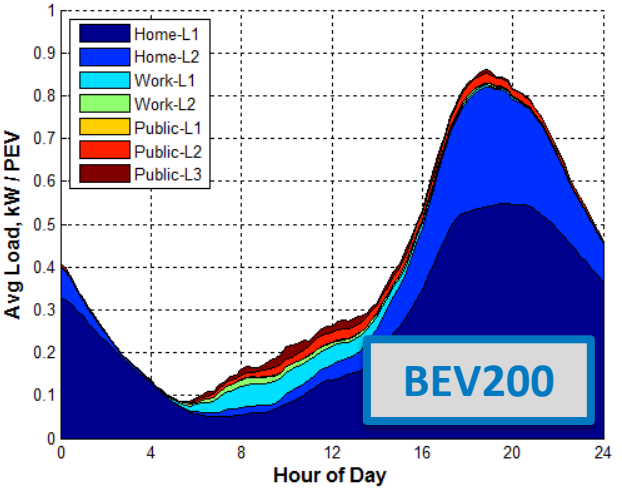
Note decreased reliance on public charging as vehicle e-range increases

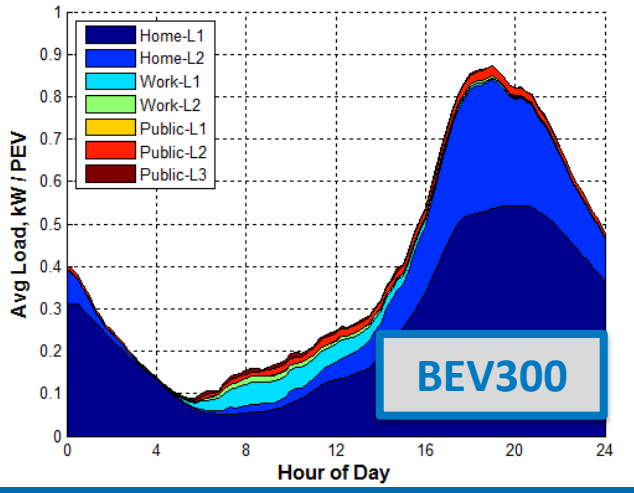












Simulated consumer selections for work and public charging by vehicle type

Note decreased reliance on work/public charging as vehicle e-range increases

	PHEV20	PHEV40	PHEV60	BEV100	BEV200	BEV300
None	69.9%	83.5%	90.0%	91.2%	92.1%	90.9%
Work Level 1	28.7%	14.9%	8.1%	7.4%	6.9%	8.1%
Work Level 2	1.3%	1.6%	1.9%	1.4%	1.0%	1.0%

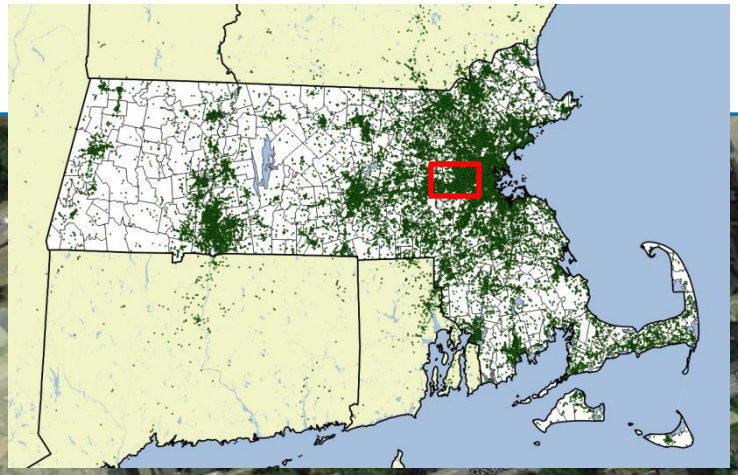
Example 1
8.1% of BEV300 owners select workplace access to Level 1

	PHEV20	PHEV40	PHEV60	BEV100	BEV200	BEV300
None	75.6%	87.5%	92.0%	87.9%	90.0%	89.0%
Public Level 1	1.6%	0.8%	0.6%	0.3%	0.3%	0.3%
Public Level 2	22.8%	11.7%	7.5%	4.0%	3.0%	3.9%
Public DCFC	0.0%	0.0%	0.0%	7.8%	6.8%	6.8%

Example 2
7.8% of BEV100 owners select public access to DCFC

How much shared use of public charging stations can be anticipated?

In addition to temporal simulation results, spatial results are surveyed to understand consumer accessibility requirements



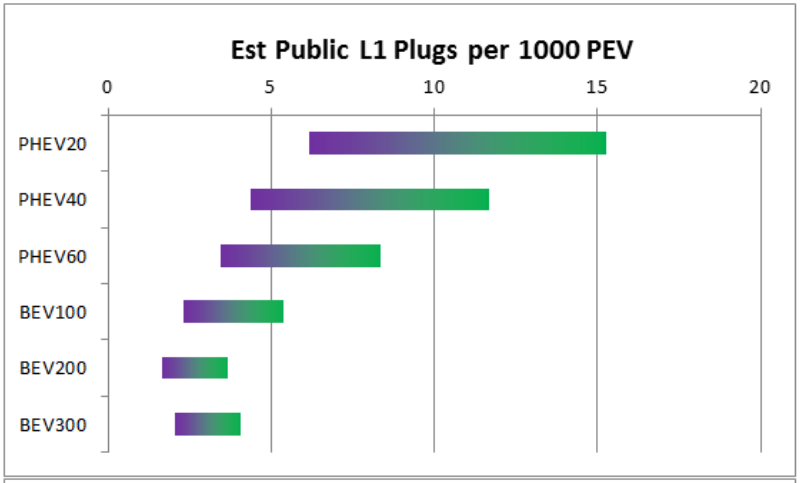
Aggregate simulated charging events to hypothetical stations within 0.1 miles (L1/L2) and 10 miles (DCFC)

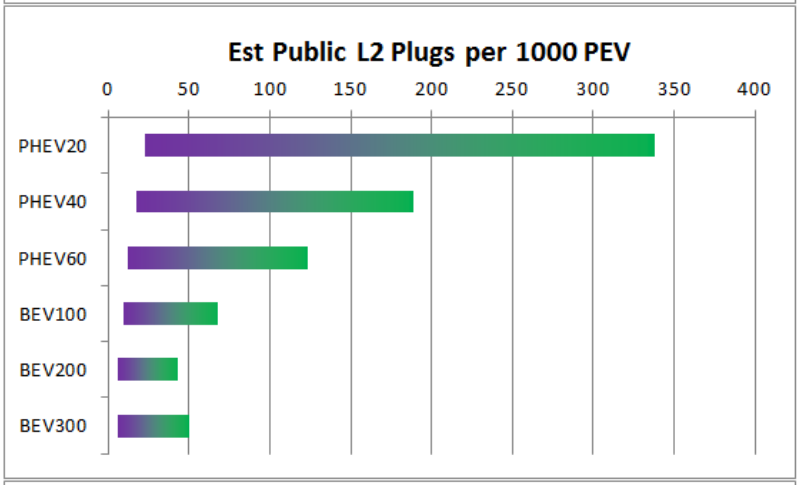
Public destination
(no simulated charging)

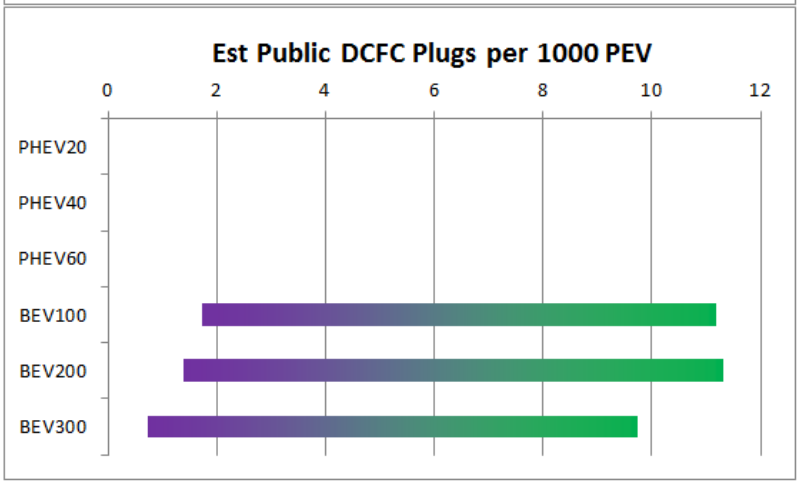
Public destination
(yes simulated charging)

Projected EVSE Rates

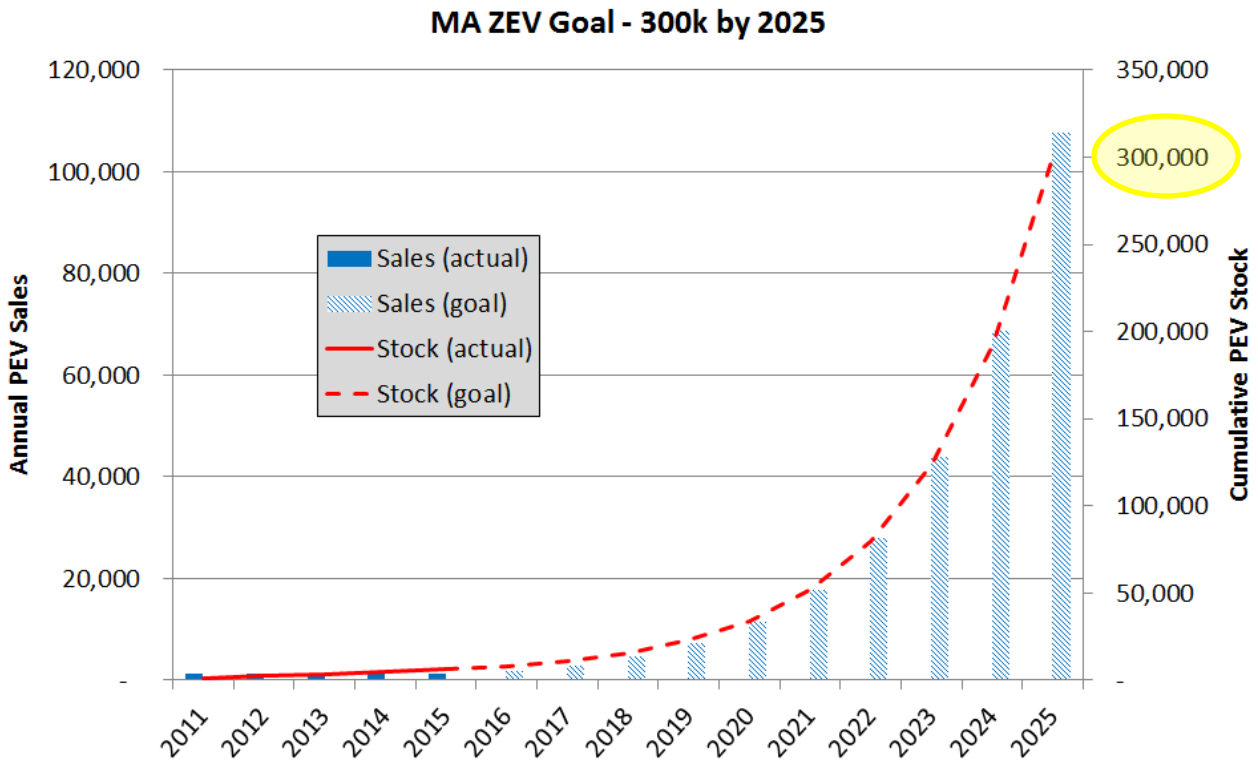
- **Projected rates for plugs per 1000 PEVs are displayed by power level and vehicle type**
- **A range of values are displayed to convey scenarios that are relatively conservative or aggressive with regard to infrastructure planning**
  - Conservative scenario is sized to exactly meet consumer peak power demands (neglecting spatial coverage)
  - Aggressive scenario is sized to fully satisfy spatial/temporal simulation results (based on low density travel data)







Multi-State ZEV Action Plan



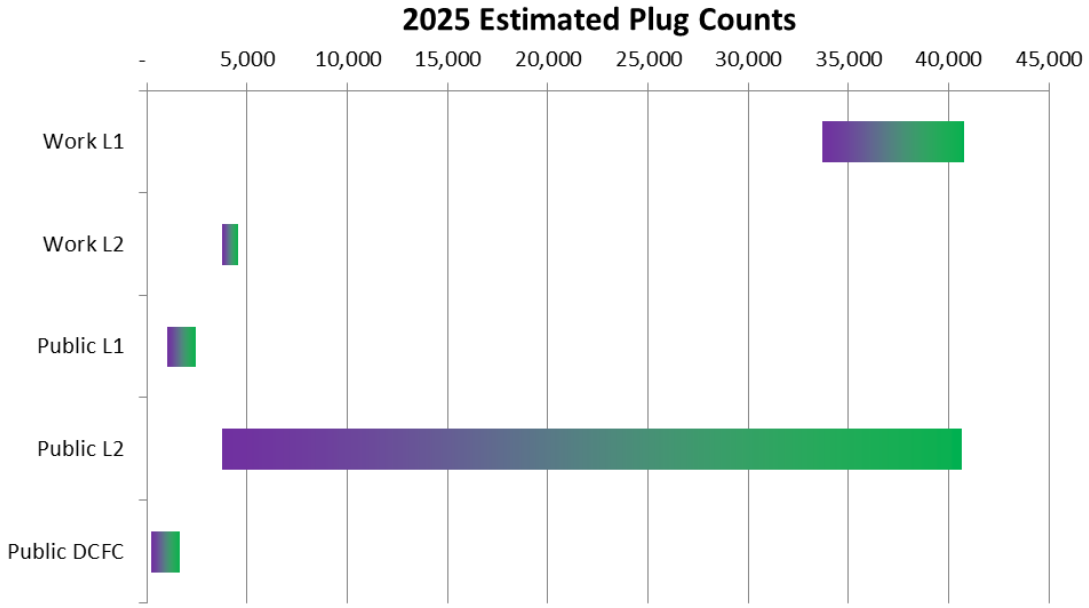
- Massachusetts contribution to multi-state ZEV action plan is 300,000 vehicles by 2025
- Requires 57% annual growth in PEV sales over the next 10 years

Projected EVSE Plugs

More Conservative — More Aggressive

- State estimate ranges from 37,413 to 45,270 workplace plugs
- Corresponds to 125 to 151 plugs per 1000 PEVs in the 2025 300k PEV scenario

- State estimate ranges from 4,935 to 44,645 public plugs
- Corresponds to 17 to 149 plugs per 1000 PEVs in the 2025 300k PEV scenario



Sources of Uncertainty
Vehicle sales mix
MUD access to home charging
PHEV demand for public charging
Shared use of public infrastructure
Day-to-day travel variability
Consumer tolerance for destination/station proximity

Thanks! Questions?

The US Department of Energy funded this work. We wish to thank our Vehicle Technologies Office sponsors Bob Graham, Jake Ward, Rachael Nealer, and Dave Gohlke.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Appendix

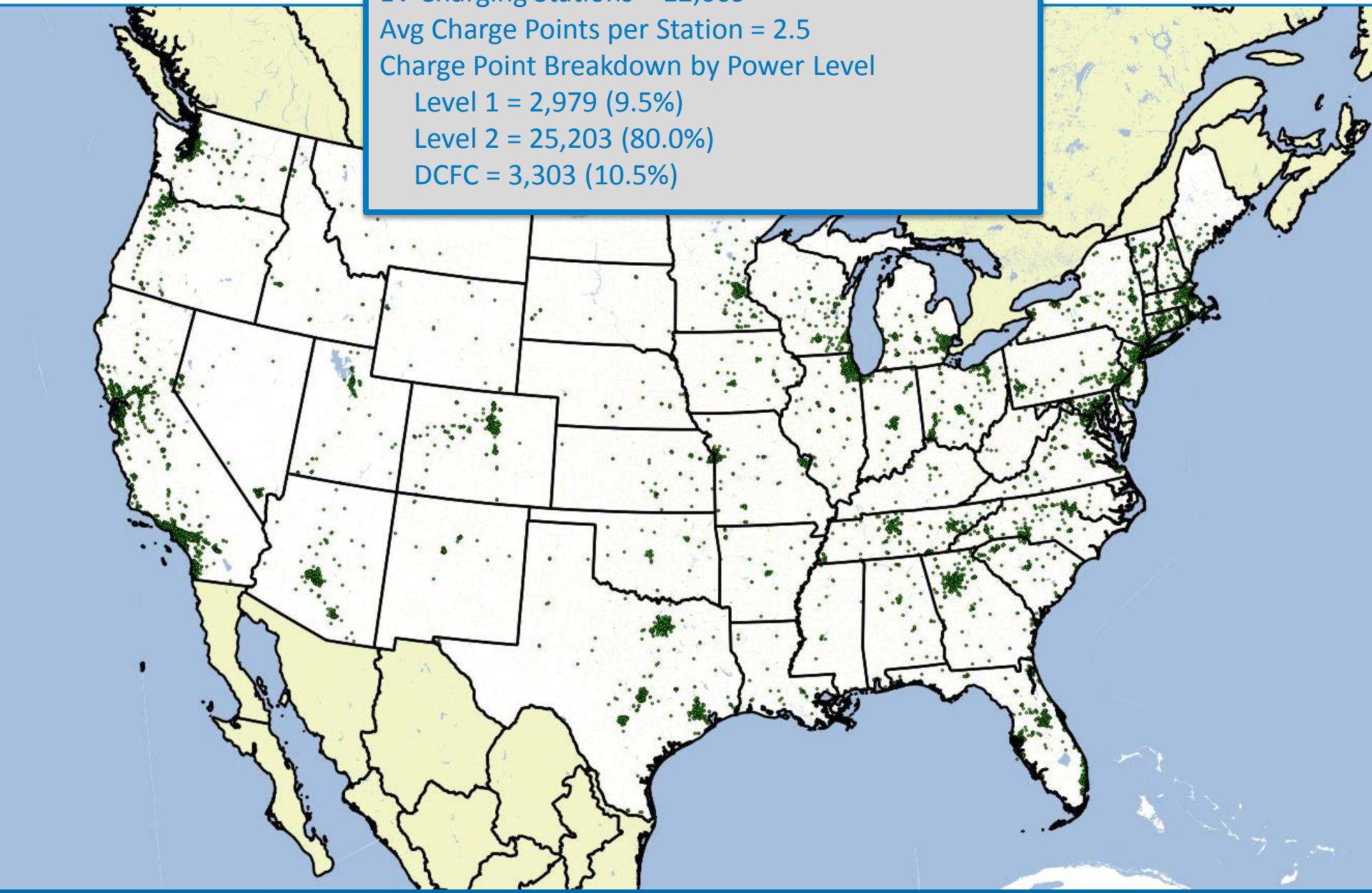
AFDC Stats thru 2015

EV Charging Stations = 12,609

Avg Charge Points per Station = 2.5

Charge Point Breakdown by Power Level

- Level 1 = 2,979 (9.5%)
- Level 2 = 25,203 (80.0%)
- DCFC = 3,303 (10.5%)



PEV Registrations thru 2015

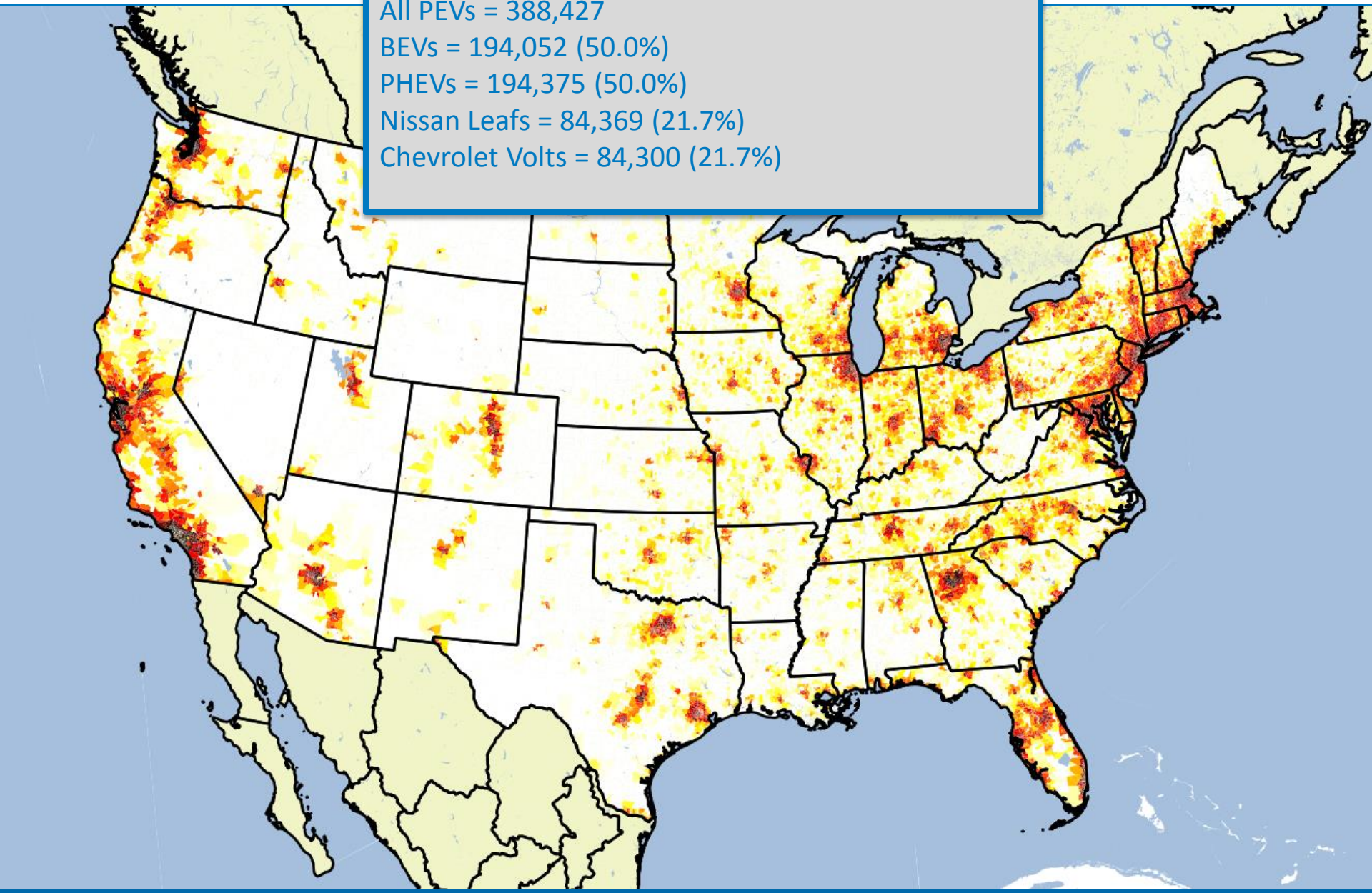
All PEVs = 388,427

BEVs = 194,052 (50.0%)

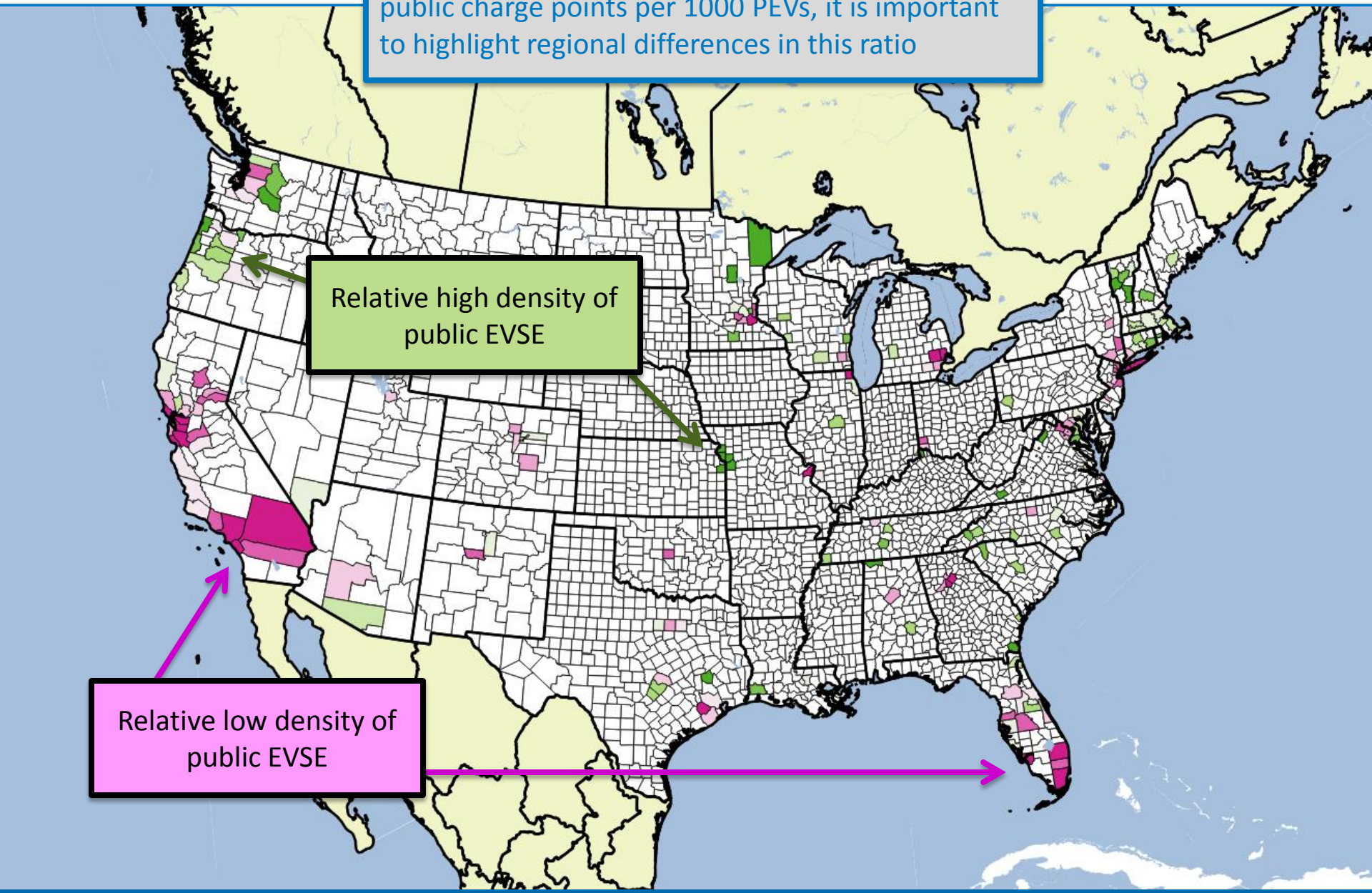
PHEVs = 194,375 (50.0%)

Nissan Leafs = 84,369 (21.7%)

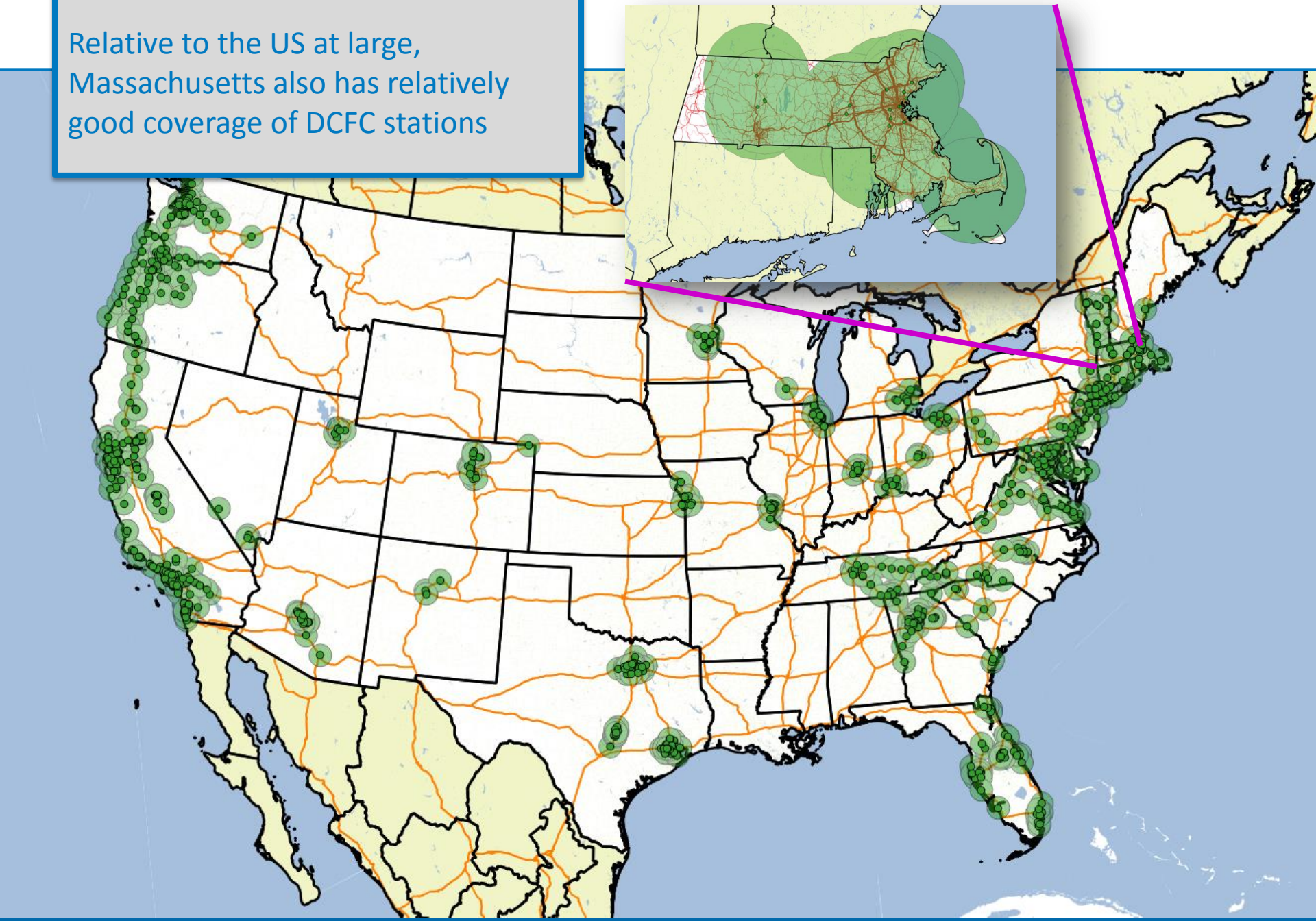
Chevrolet Volts = 84,300 (21.7%)



While the average US county currently provides 43 public charge points per 1000 PEVs, it is important to highlight regional differences in this ratio

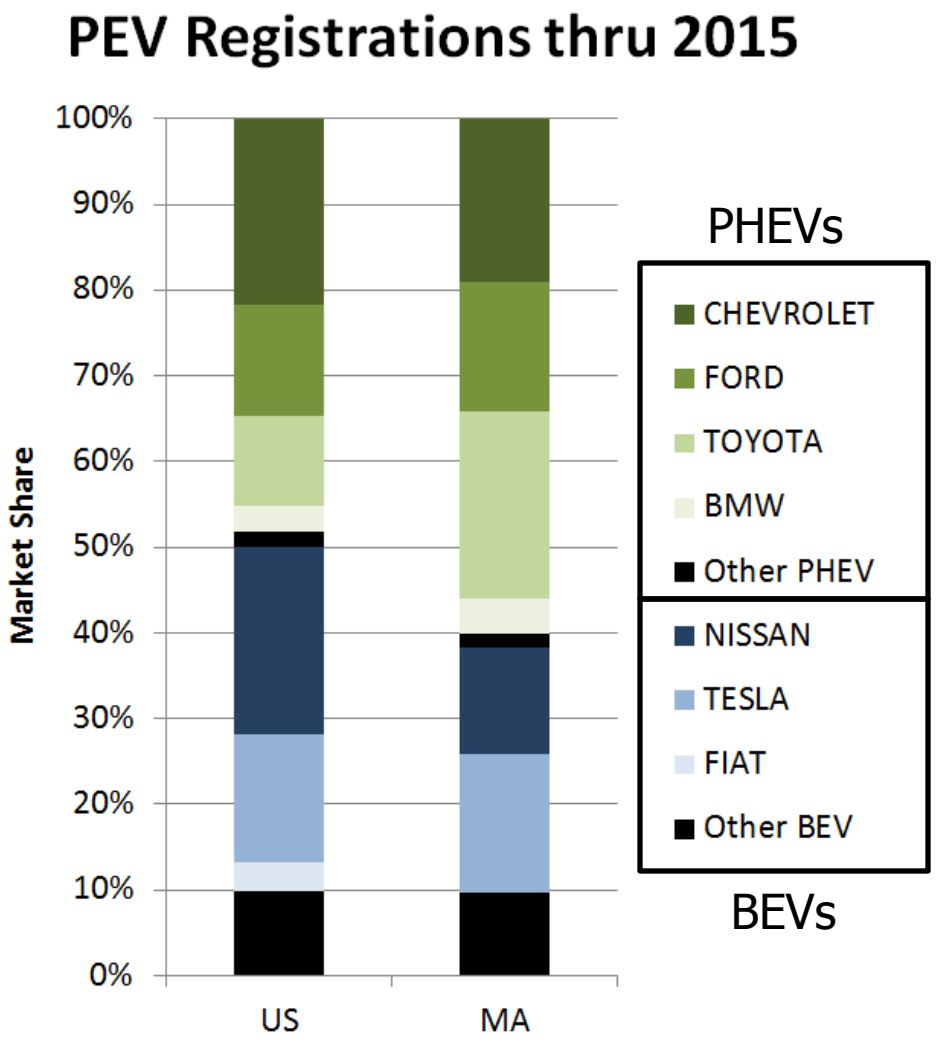


Relative to the US at large, Massachusetts also has relatively good coverage of DCFC stations

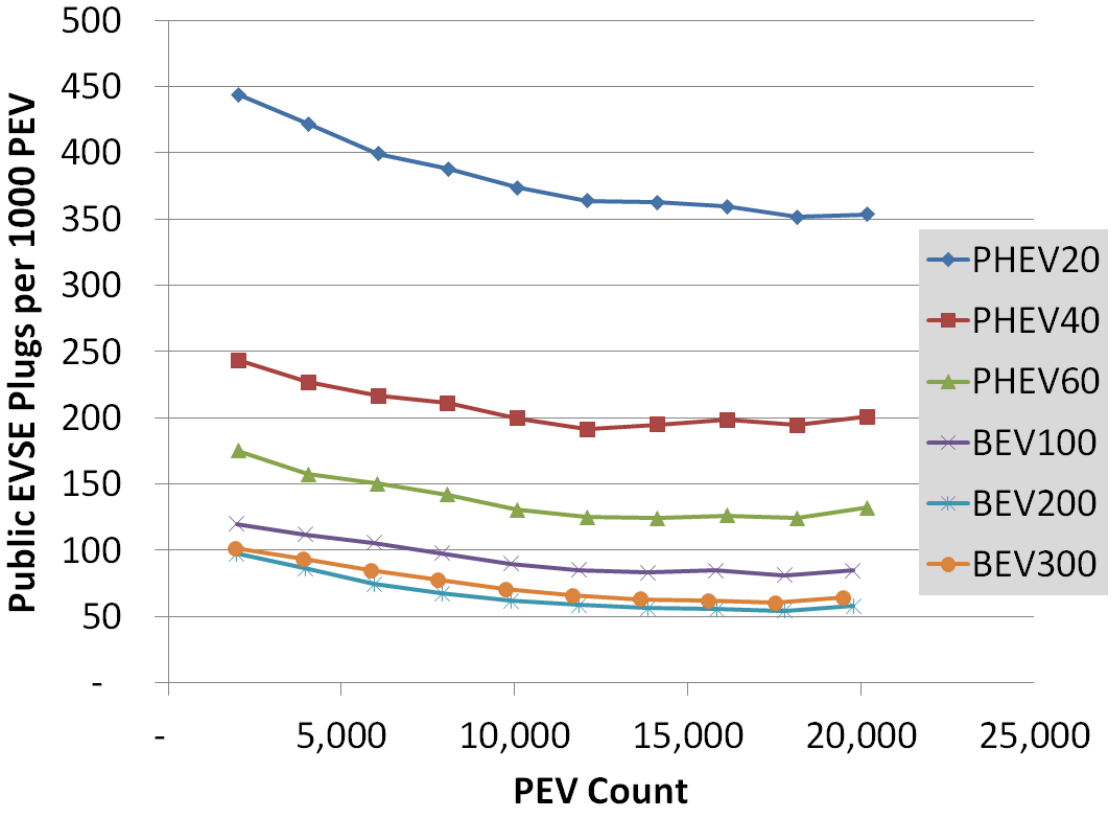


MA has a slightly higher preference for PHEVs compared to the national average.

Relative to the national PEV mix, Toyota Plug-In Prius is about twice as popular in MA while the Nissan Leaf is about half as popular.

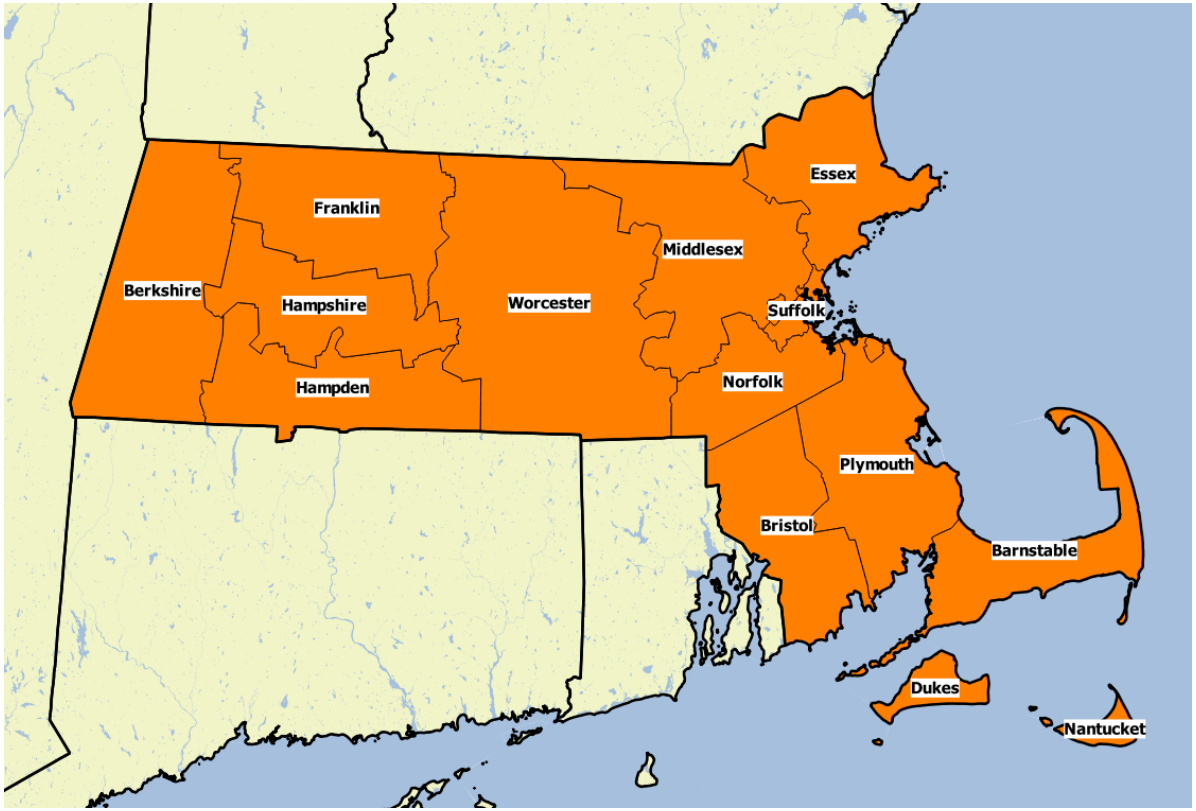


- MTS sample includes 20,177 vehicles with travel activity
- Public infrastructure is assessed using aggressive spatial/temporal requirements over a range of random samples of the MTS
- Increased ability for consumers to share plugs is observed as PEV density in the region increases



- The 2025 goal of 300,000 PEVs is distributed by county using projections from Massachusetts Executive Office of Energy and Environmental Affairs and by housing type using vehicle stock information from the 2011 Massachusetts Travel Survey
- Statewide 20% of PEVs allocated to MUDs

County	SUD	MUD
Barnstable County	2.2%	0.2%
Berkshire County	1.4%	0.2%
Bristol County	2.5%	0.8%
Dukes County	0.8%	0.0%
Essex County	10.3%	2.3%
Franklin County	0.9%	0.2%
Hampden County	4.8%	1.0%
Hampshire County	4.1%	0.8%
Middlesex County	28.5%	7.4%
Nantucket County	0.3%	0.0%
Norfolk County	9.0%	1.8%
Plymouth County	4.8%	0.6%
Suffolk County	2.2%	3.1%
Worcester County	7.9%	1.7%



SUD: Single unit dwelling **MUD:** Multi unit dwelling

More Conservative — More Aggressive