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Electric Transportation

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Energy and Climate Change Research Seminar

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Mainstream PEV Commercialization Began December 2010

Chevrolet Volt

- Extended Range Electric Vehicle (EREV - A plug-in hybrid with a guaranteed electric range).
- 25-50 mile advertised range
- Charging: 8-10 hours at 120V, 12A
  3-4 hours at 240V, 15A

Nissan Leaf

- Battery Electric Vehicle
- 100-mile advertised range
- Charging: 20 hours at 120V, 12A
  8 hours at 240V, 15A
  30 min at 400V, 150A

Battery Electric Vehicles

- Plug-in vehicle with rechargeable battery only
- Driving range limited by battery size – industry norm for range ~ 100 miles
  - Tesla is exception, offering longer range
- Nominal recharge time of about eight hours (fully depleted battery)
- The majority of PEV launches through 2012 are BEVs

Mitsubishi 'i' battery electric vehicle. ***Photo courtesy of Mitsubishi.***

Ford Focus Electric battery electric vehicle. ***Photo courtesy of Ford.***

Plug-In Hybrid Electric Vehicles

- Plug-in vehicle with rechargeable battery
- Internal combustion engine allows for extended driving
- Typically based on hybrid vehicle technology (e.g. Prius Plug-In)
- 10 – 40 miles electric range
- Likely to blend electricity and gasoline at higher speeds, power

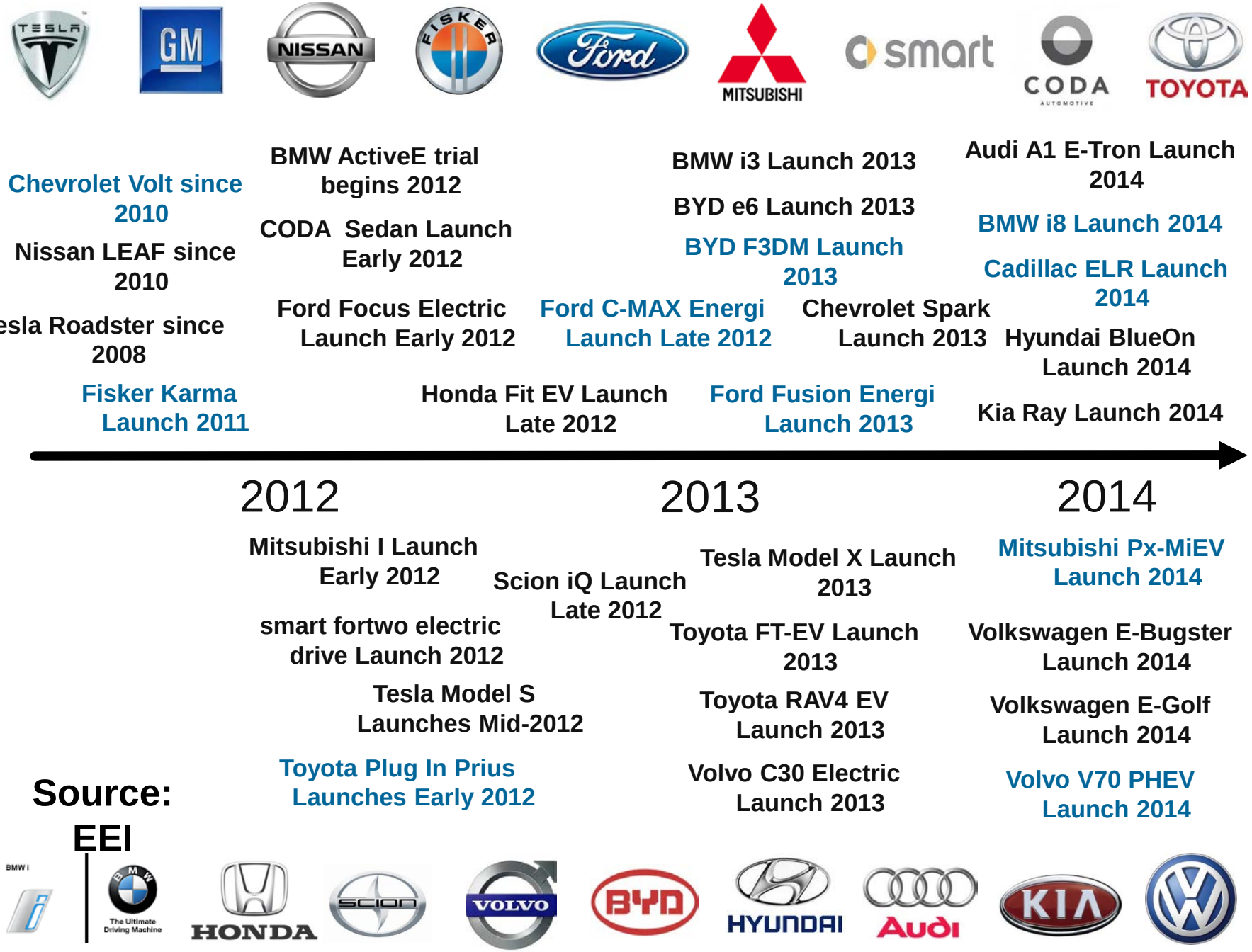
Toyota Prius Plug-In Hybrid. ***Photo courtesy of Toyota.***

Ford C-MAX Energi plug-in hybrid. ***Photo courtesy of Ford.***

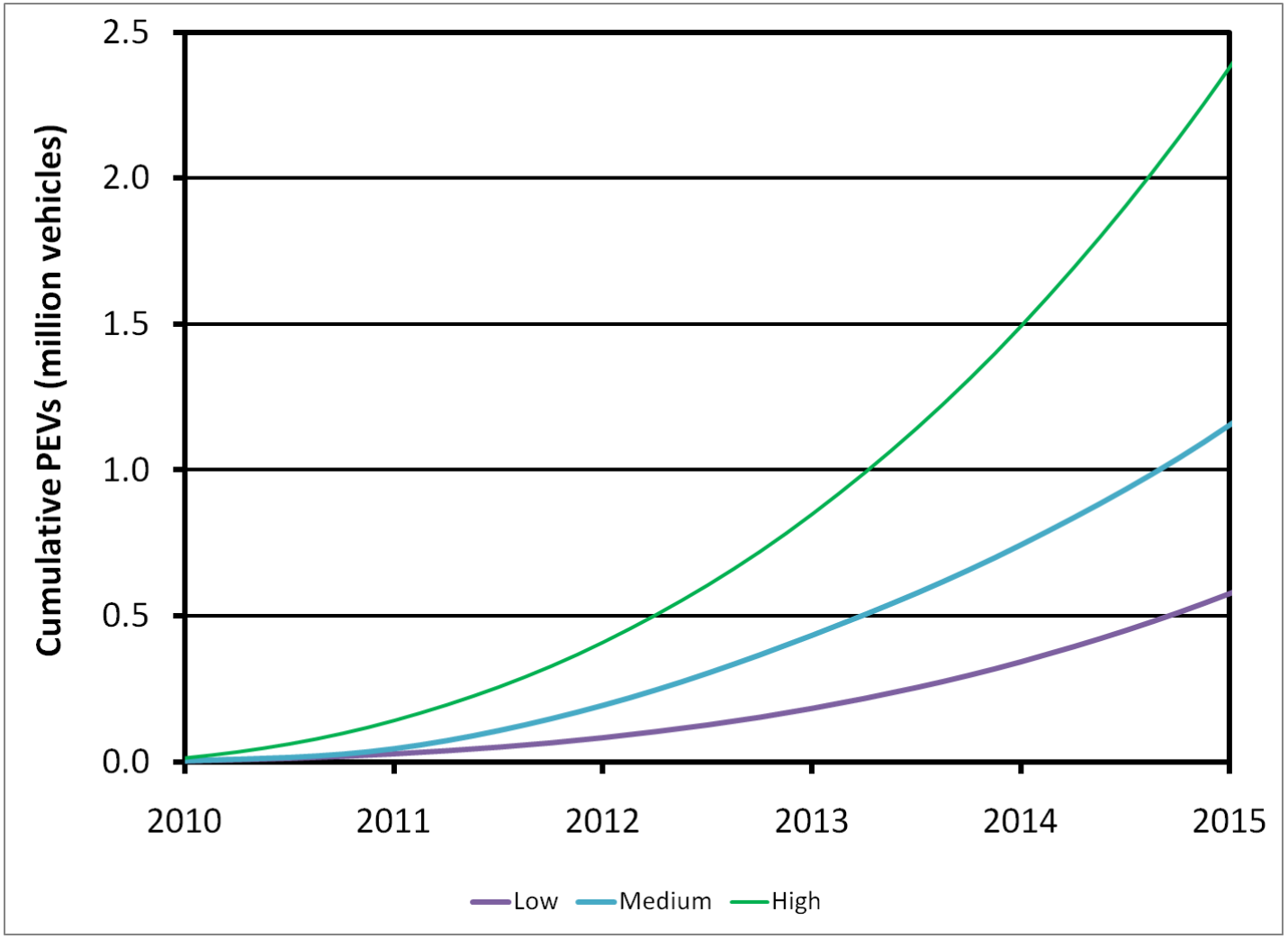
Extended Range Electric Vehicle

- A type of PHEV—rechargeable battery plus a combustion engine
- EREVs drive like BEVs until battery is depleted then switch to hybrid mode
- Something of a ‘new’ category
  - Many consider to be distinct and separate category from PHEVs
- EREVs can also drive for extended distances between charges using engine
- Electric range typically longer, 25-50 miles

Chevrolet Volt Extended Range Electric Vehicle (EREV). ***Photo courtesy of General Motors***

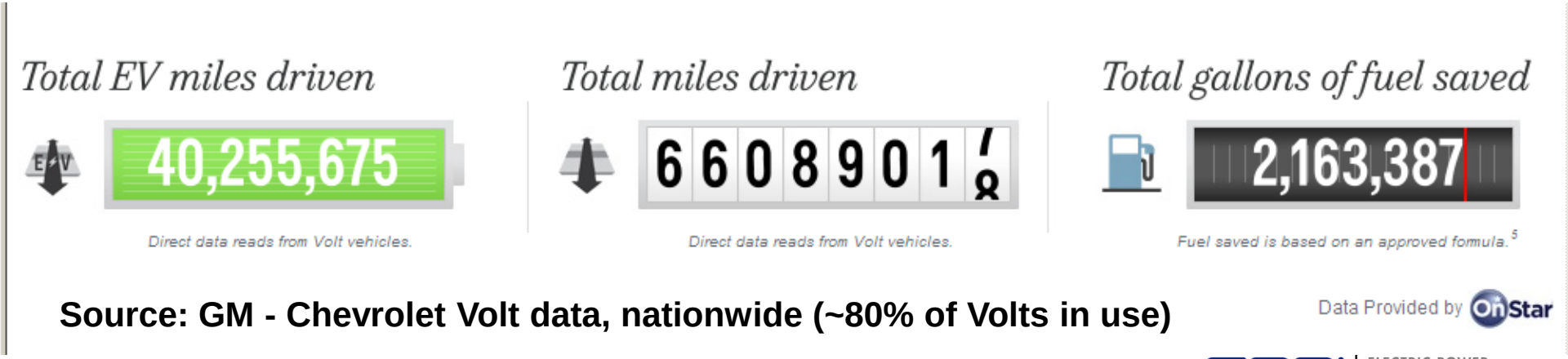

Chevrolet Volt since 2010
Nissan LEAF since 2010
Tesla Roadster since 2008
Fisker Karma Launch 2011
BMW ActiveE trial begins 2012
CODA Sedan Launch Early 2012
Ford Focus Electric Launch Early 2012
Honda Fit EV Launch Late 2012
Ford C-MAX Energi Launch Late 2012
BMW i3 Launch 2013
BYD e6 Launch 2013
BYD F3DM Launch 2013
Ford Fusion Energi Launch 2013
Chevrolet Spark Launch 2013
Audi A1 E-Tron Launch 2014
BMW i8 Launch 2014
Cadillac ELR Launch 2014
Hyundai BlueOn Launch 2014
Kia Ray Launch 2014
2012
2013
2014
Mitsubishi I Launch Early 2012
smart fortwo electric drive Launch 2012
Tesla Model S Launches Mid-2012
Toyota Plug In Prius Launches Early 2012
Scion iQ Launch Late 2012
Tesla Model X Launch 2013
Toyota FT-EV Launch 2013
Toyota RAV4 EV Launch 2013
Volvo C30 Electric Launch 2013
Mitsubishi Px-MiEV Launch 2014
Volkswagen E-Bugster Launch 2014
Volkswagen E-Golf Launch 2014
Volvo V70 PHEV Launch 2014
Source: EEI

Cumulative PEV Sales from 2010 – 2015



Early Insights from PEV Data

- Drivers plug in—often
- The vehicles are extremely well-received
- 120 volt home charging is very popular, even for battery EVs
- A typical recharge is not a lot of energy ~ 6 kWh
- Charge power and battery capability are increasing rapidly with new models



Source: GM - Chevrolet Volt data, nationwide (~80% of Volts in use)

Data Provided by OnStar

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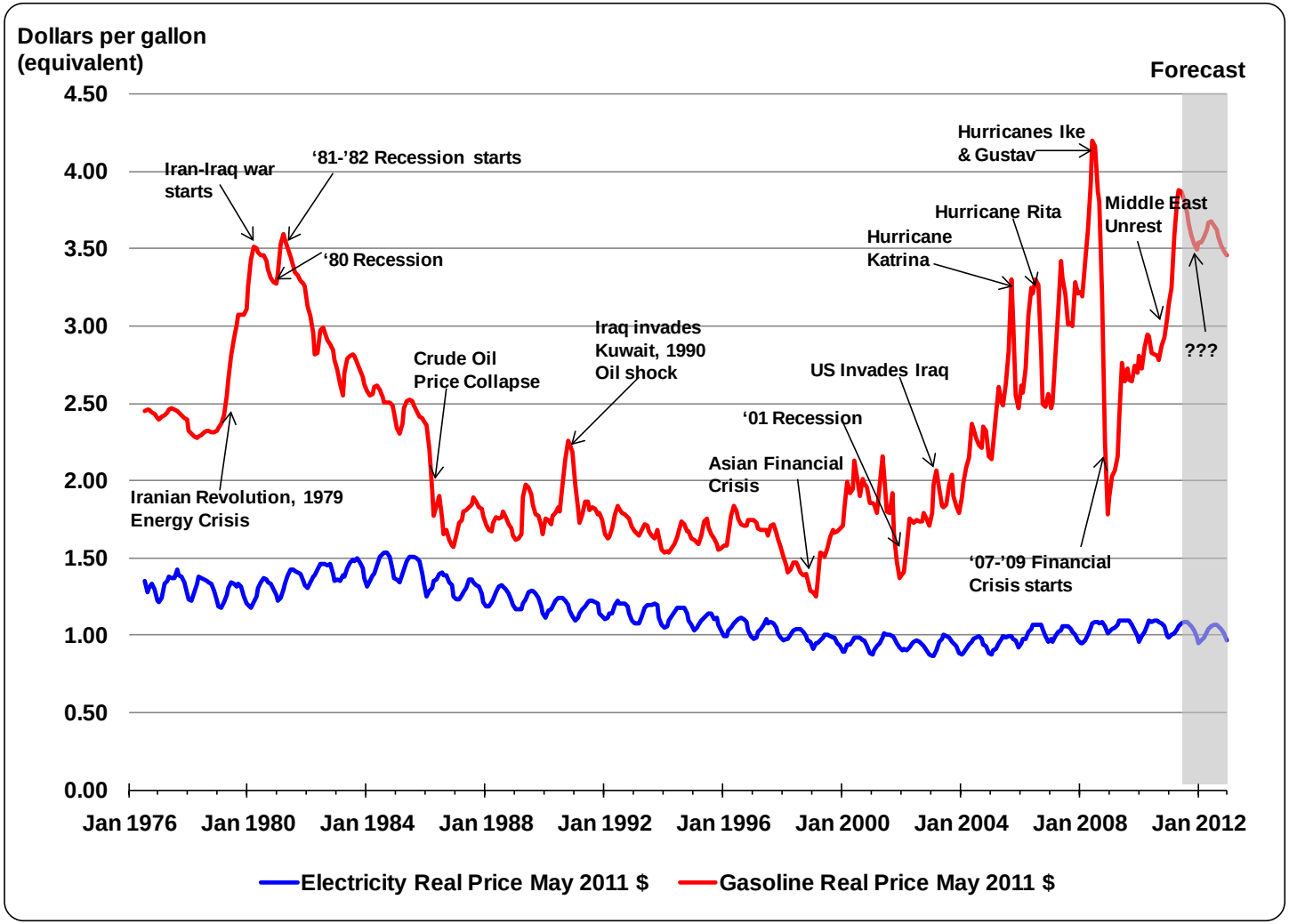
Electricity Pricing for PEVs

Electricity is an inexpensive, relatively stable transportation fuel



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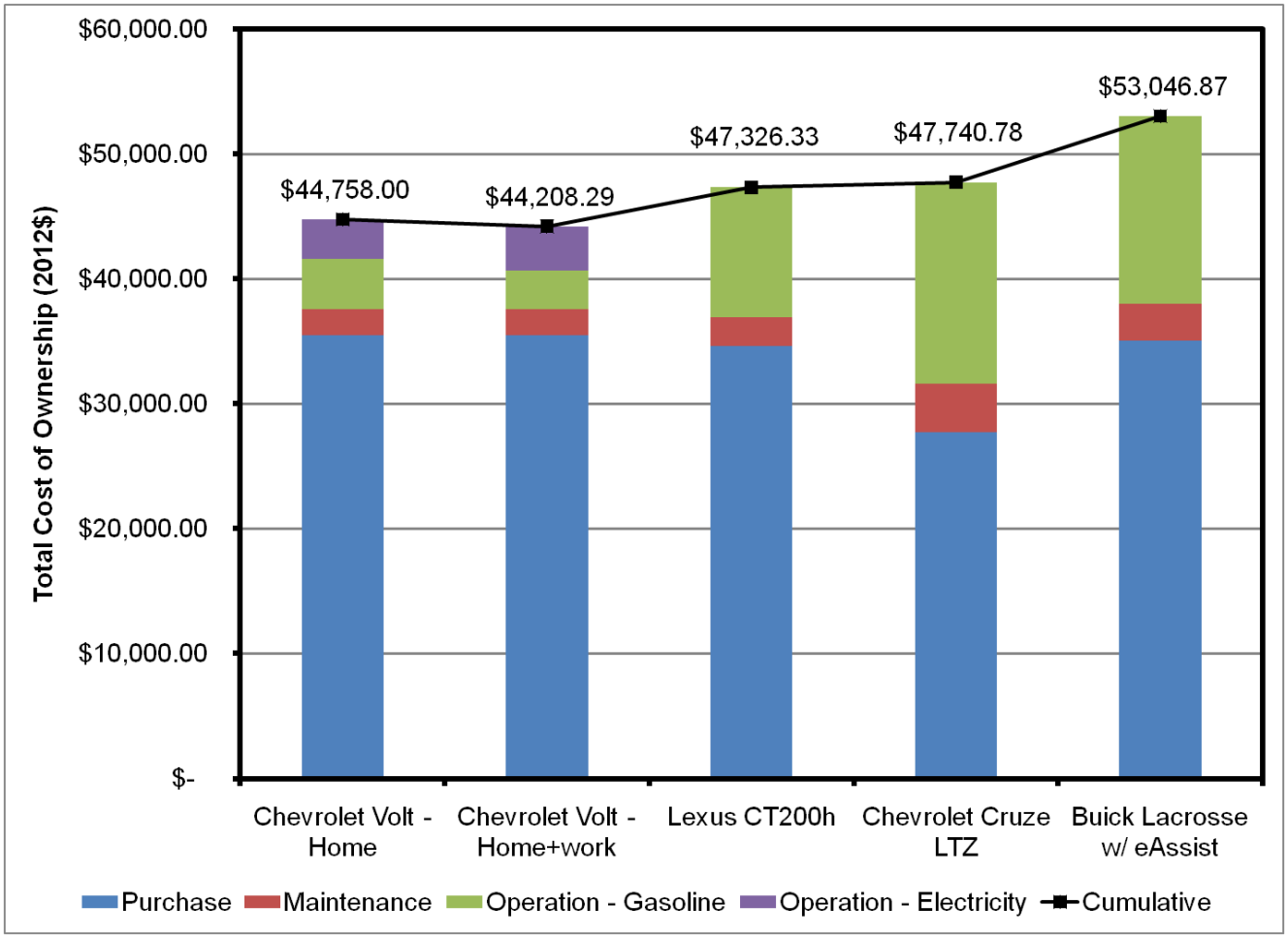
PEV Cost of Ownership is Competitive

Chevrolet Volt – 10 Year Total Cost of Ownership



10,000 – 12,500 miles per year

Charging Infrastructure
PEVs Generally Have Three Charging Options

120V – Level 1

Portable cordset
Use any 120V outlet

Up to 1.44 kW

DC Fast Charging

Up to ~ 50 – 60 kW

Fast, expensive

Standard not yet in place

240V – Level 2

Permanent charge station (EVSE)

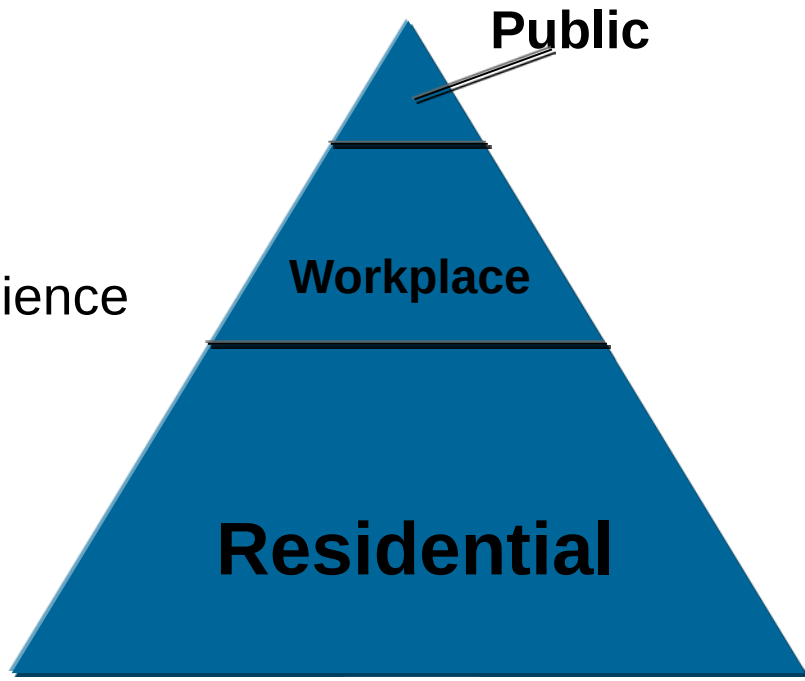
Typ. 3.3 – 6.6 kW, but up to 19.2 kW

A Few Points about PEV Infrastructure

- You need less of it than you think—however societal benefit can increase with more
- **PEVs are a paradigm shift – weekly refueling versus daily recharging will drive charging behavior**
- Don’t underestimate the ‘power’ of Level 1 charging
- Keep an eye on DC fast charging
- Highly scaled future charging will be smart and in many cases fast
- **We have to understand the PEV driver’s value proposition for charging**

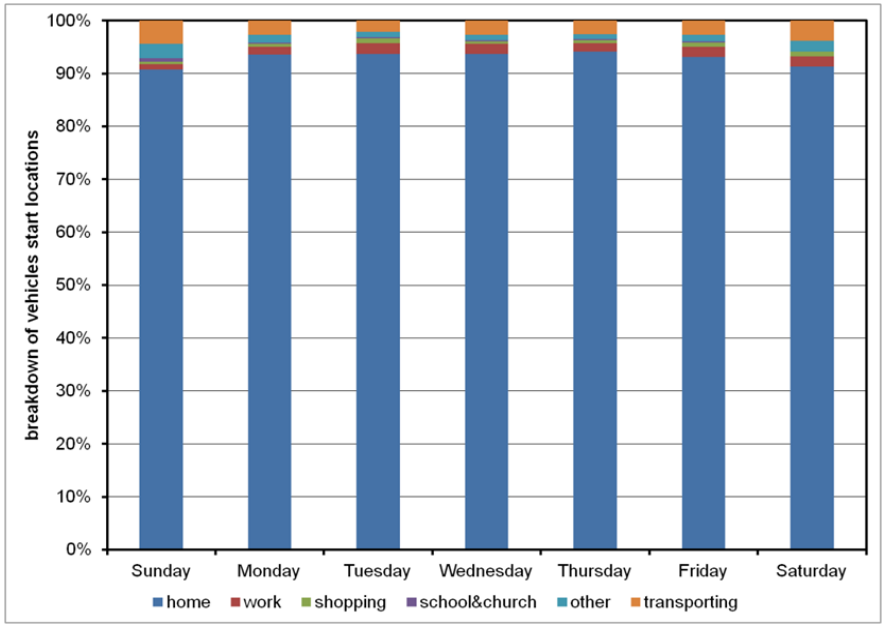
Planning and Implementing Infrastructure

- **Infrastructure can be expensive**
  - ~ $1500 home, $2500+ public
- **Focus on Residential**
  - 95% of vehicles end day at home
  - Lower residential cost, improve convenience
- **Workplace**
  - 2nd priority in terms of use
- **Public Charging**
  - **Critical (BEV range)**
    - Regional infrastructure
  - **Convenience: Increase electricity use in PHEVs, support paradigm shift**
    - Understand value proposition, societal value

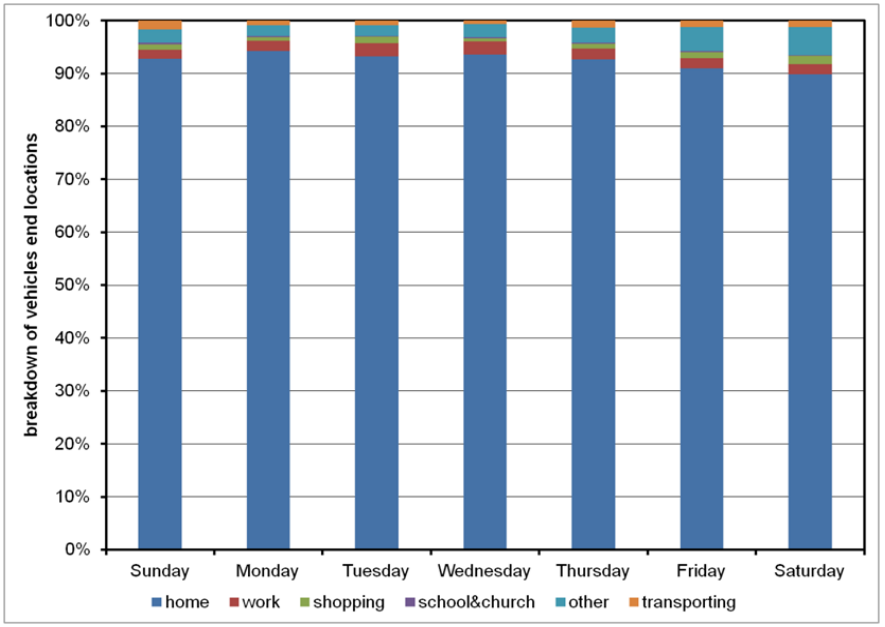


Most Charging Will Occur at Home

Most people start at home…



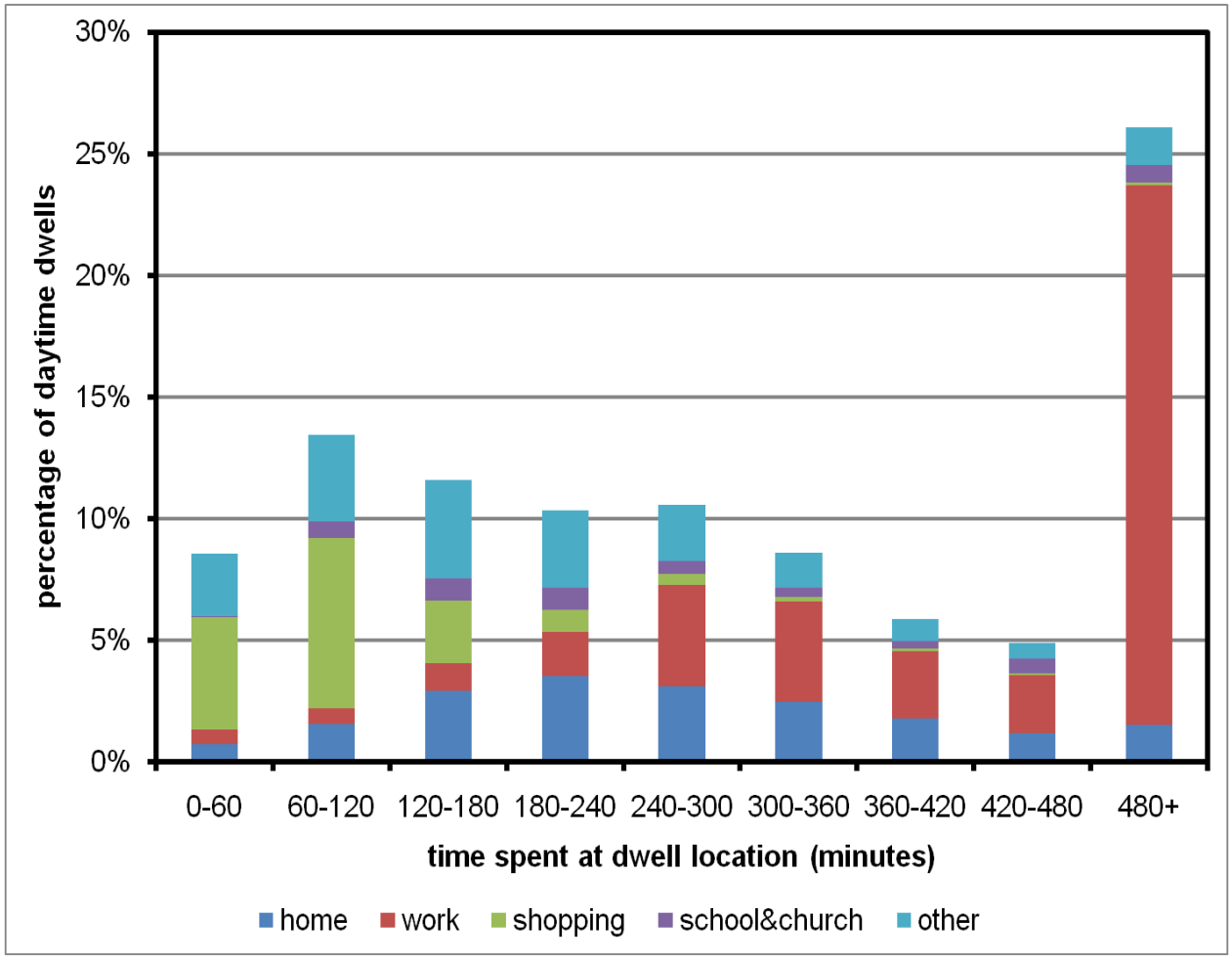
… and end at home.



There is very little variation between days – less than 5% change from weekdays and weekends.

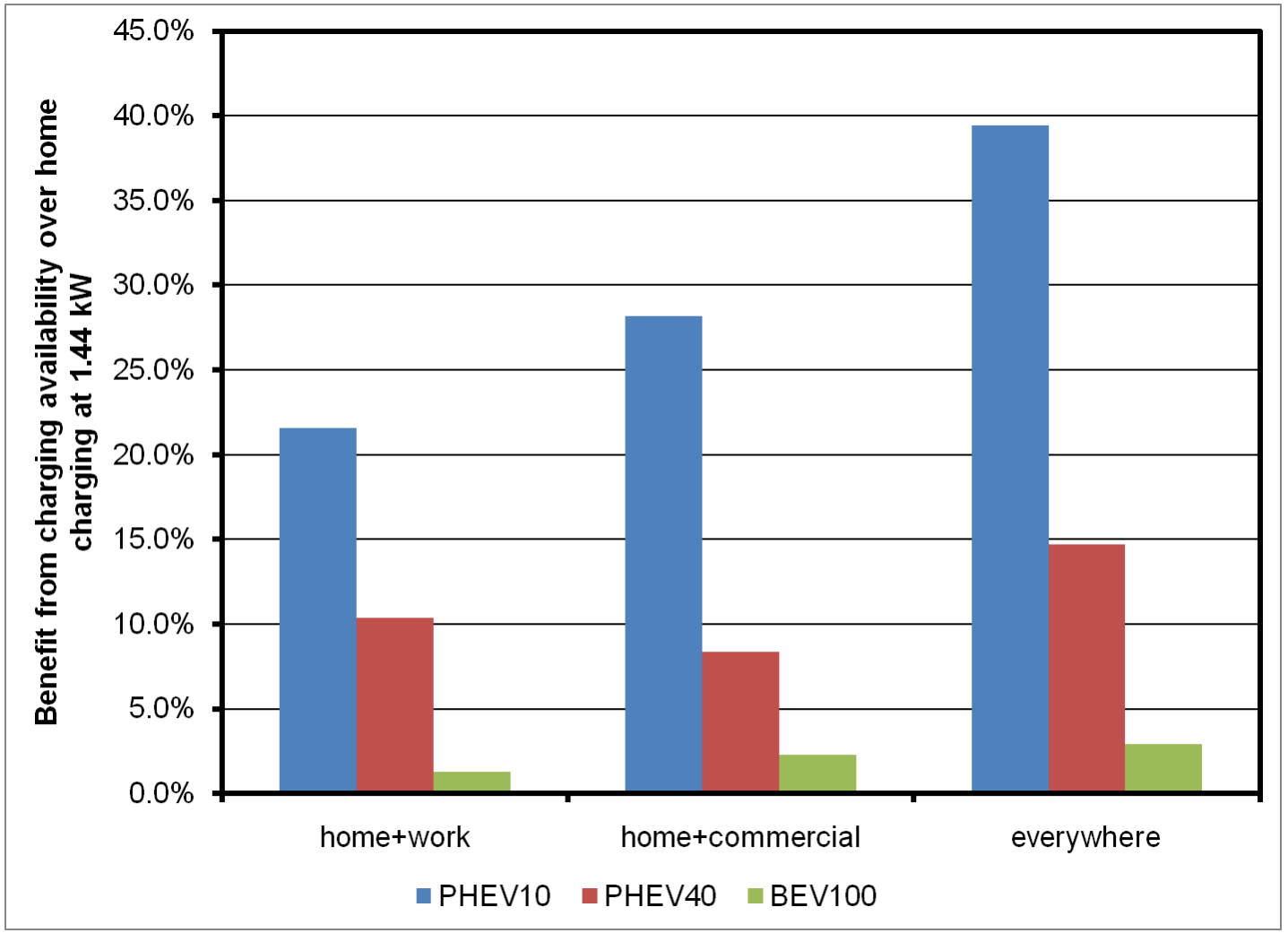
Transportation Statistics for Electric Transportation. EPRI, Palo Alto, CA: December 2011. Product ID #1021848.

However, Workplace Charging is Important

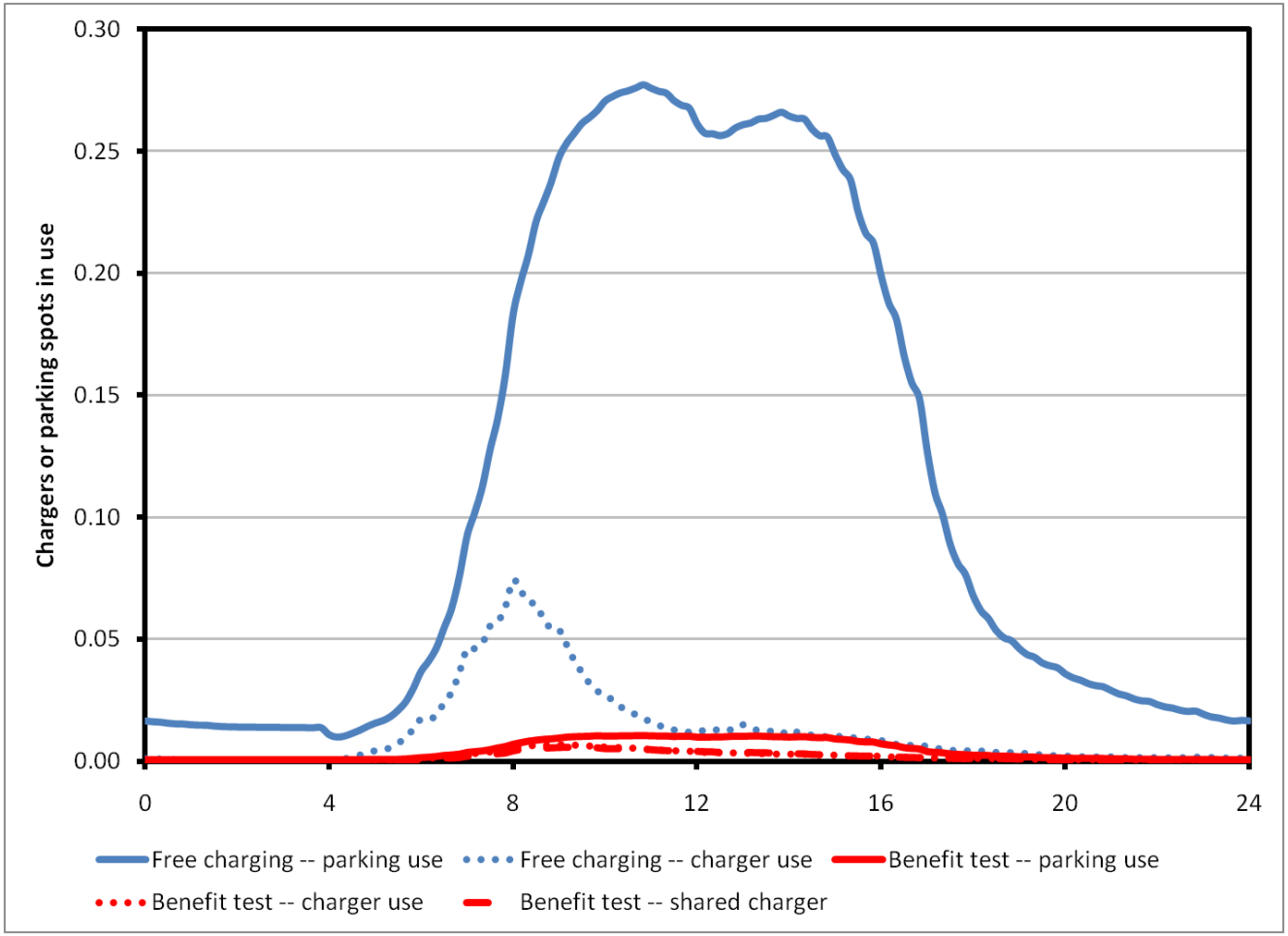


Transportation Statistics for Electric Transportation. EPRI, Palo Alto, CA: December 2011. Product ID #1021848.

PHEVs with Low Electric Range See Higher Benefits from Increased Charging

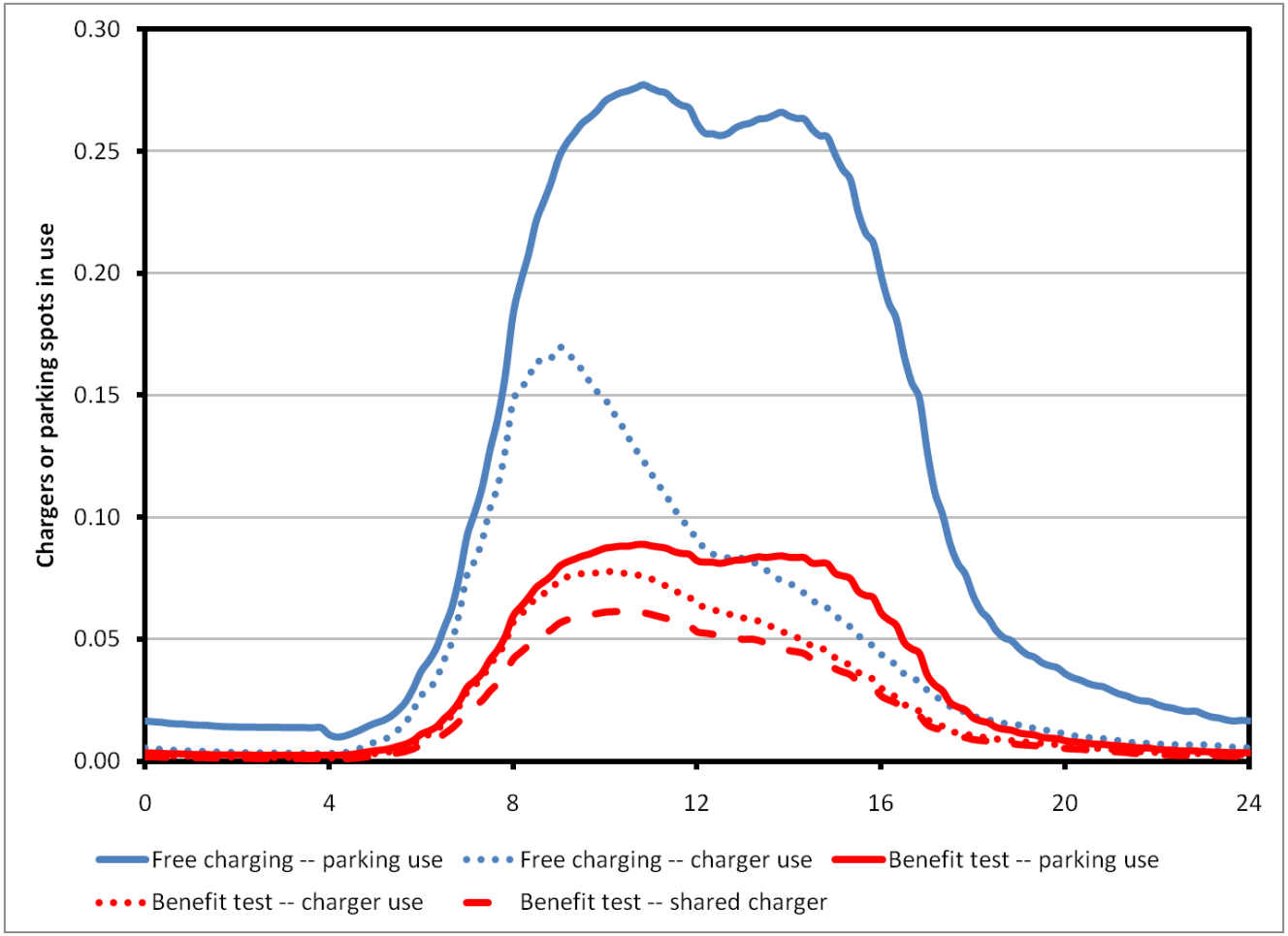


PEV Driver 'Needs and Wants' Can Differ
Workplace Charging – BEV100 6.6kW

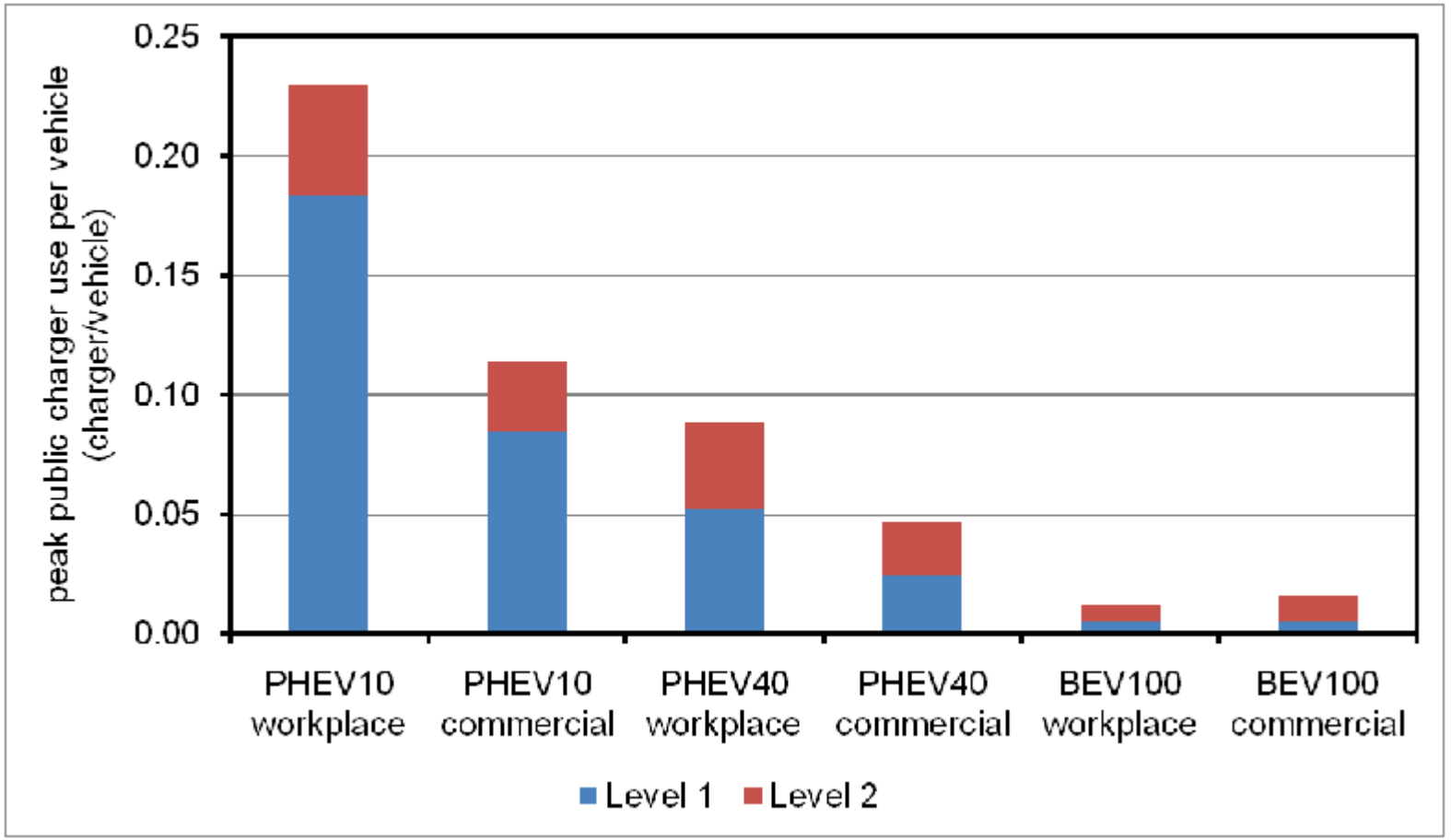


When BEV100s are only allowed to charge when needed, they charge nearly the entire time. Again, very little benefit is seen for shared-charger model.

PEV Driver 'Needs and Wants' Can Differ
Workplace Charging – PHEV40 1.44kW

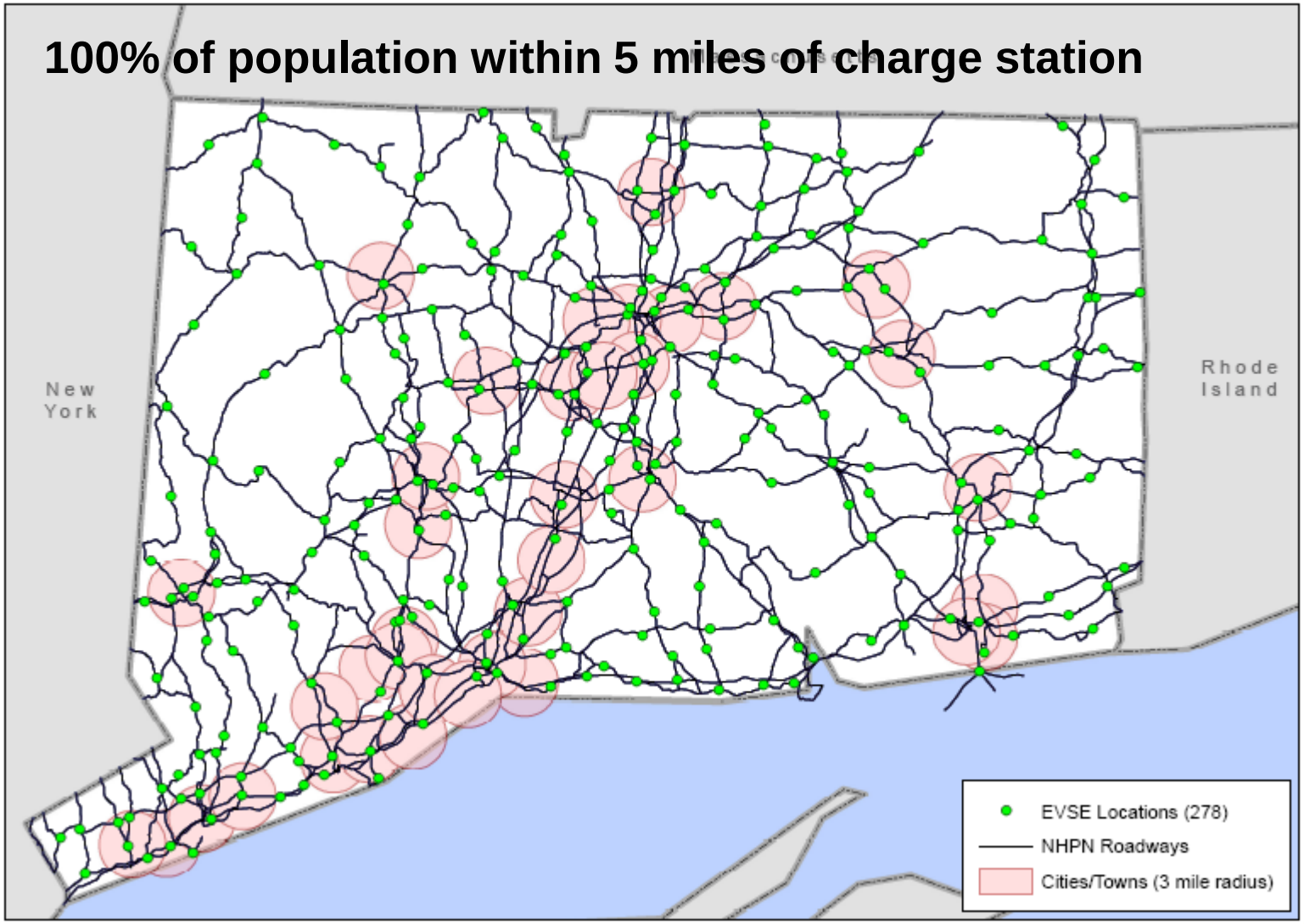


Results



Statewide or Regional Infrastructure

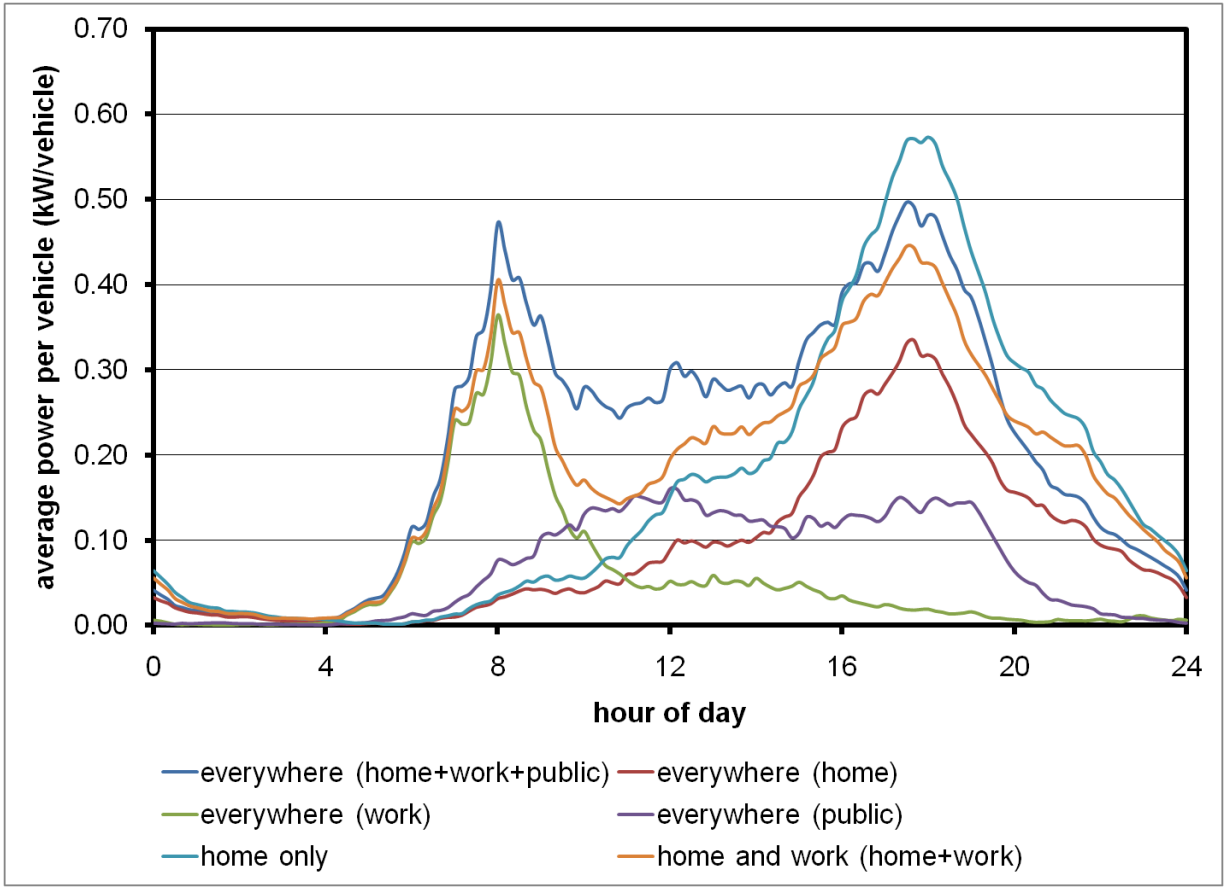
State of Connecticut Example – 275 Level 2 EVSEs



Regional Infrastructure

- Provides a ‘safety net’ for BEV drivers that might get stranded
- **Leveraging smaller town and city locations brings entire state population into EV infrastructure framework and culture**
- Is not likely to see high use
- Is not likely to be financially viable by itself
- Should be simple, reliable, safe, and secure
- Can help indicate locations for future DC fast charging locations
- Evens out some of the problems with early assumptions

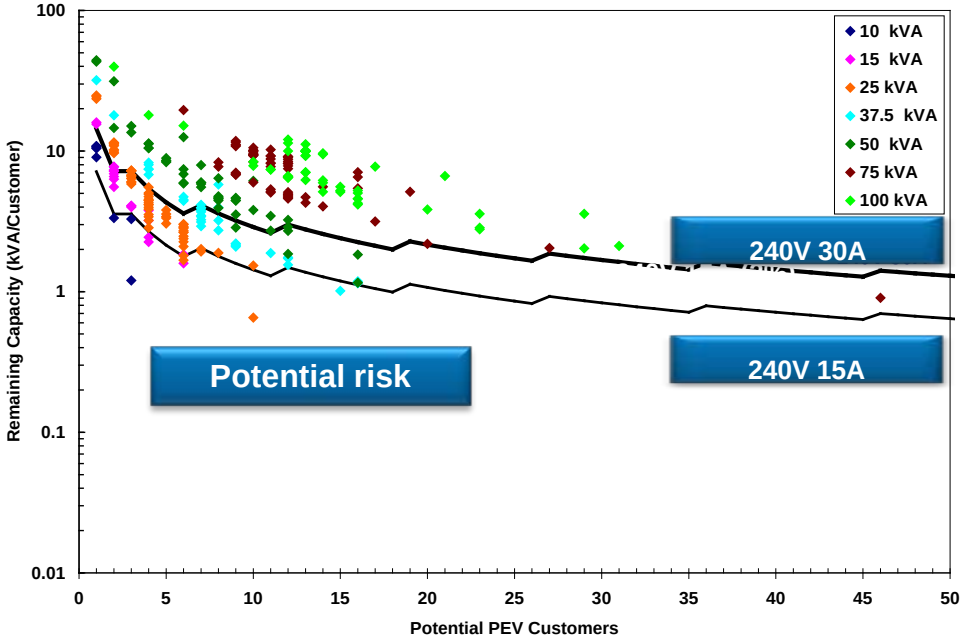
System Level Impacts of PEV Charging are Low

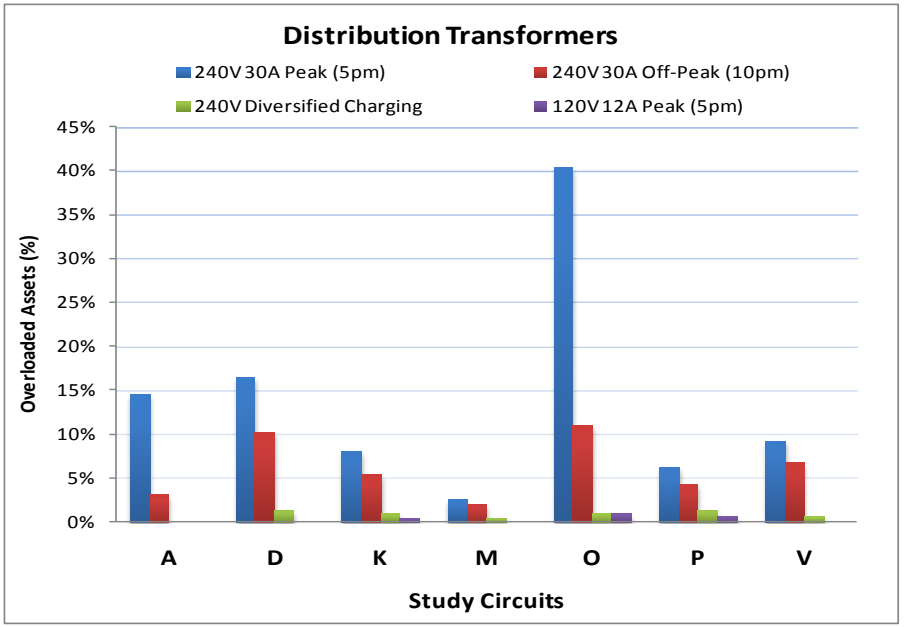


→Reducing charging availability, ultimately increases residential evening power demand

Distribution Impacts of PEV Charging

PEV can impact local distribution systems



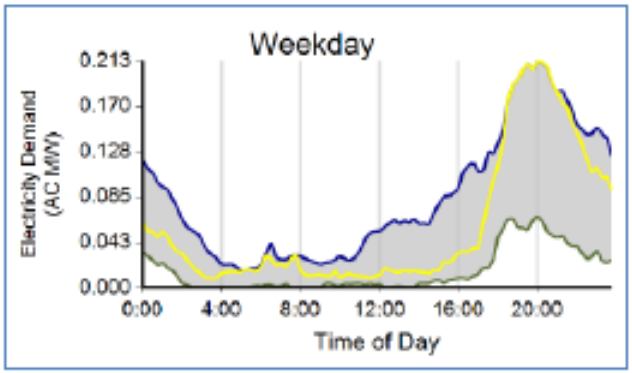


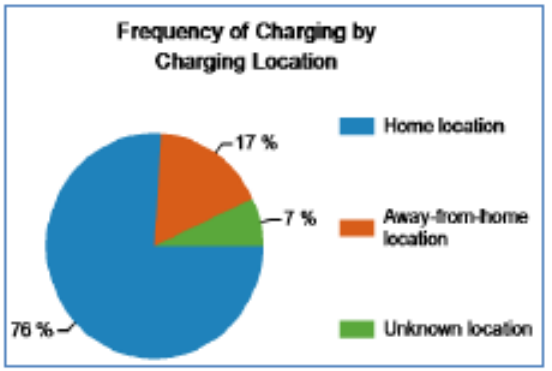
- Level of impact depends upon time-of-day and charge power
- Utility options to manage load and impacts:
  - Early notification proactive distribution planning
  - Time of use rates
  - Smart charging

Early Results Indicate Rates Can Encourage Off-Peak Charging

Nashville Electric Svc, TN

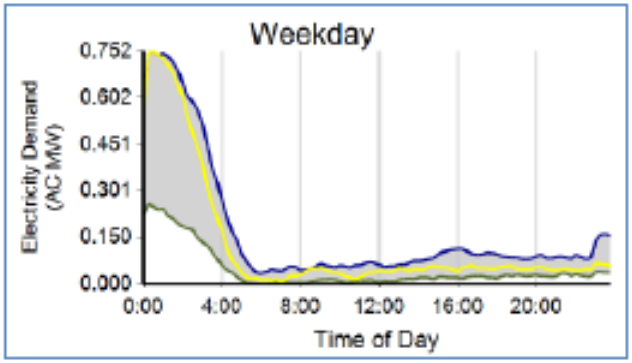
- 232 residential EVSE
- Charge: $13.43/month
- Summer $0.09263/kWh
- Winter $0.0898/kWh

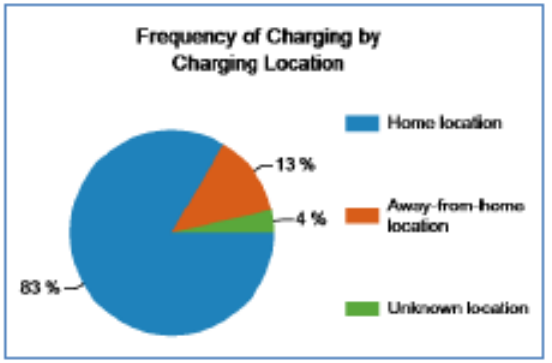




SDG&E, CA

- 461 residential EVSE
- TOU rates
- Super off-peak:
  - midnight to 5am





- But what is the influence of Price?

Charts & EVSE Count Source: INL http://avt.inl.gov/pdf/EVProj/EVProjInfrastructureQ42011.pdf

Frequency of Charging Chart: INL http://avt.inl.gov/pdf/EVProj/EVProjNissanLeafQ42011.pdf

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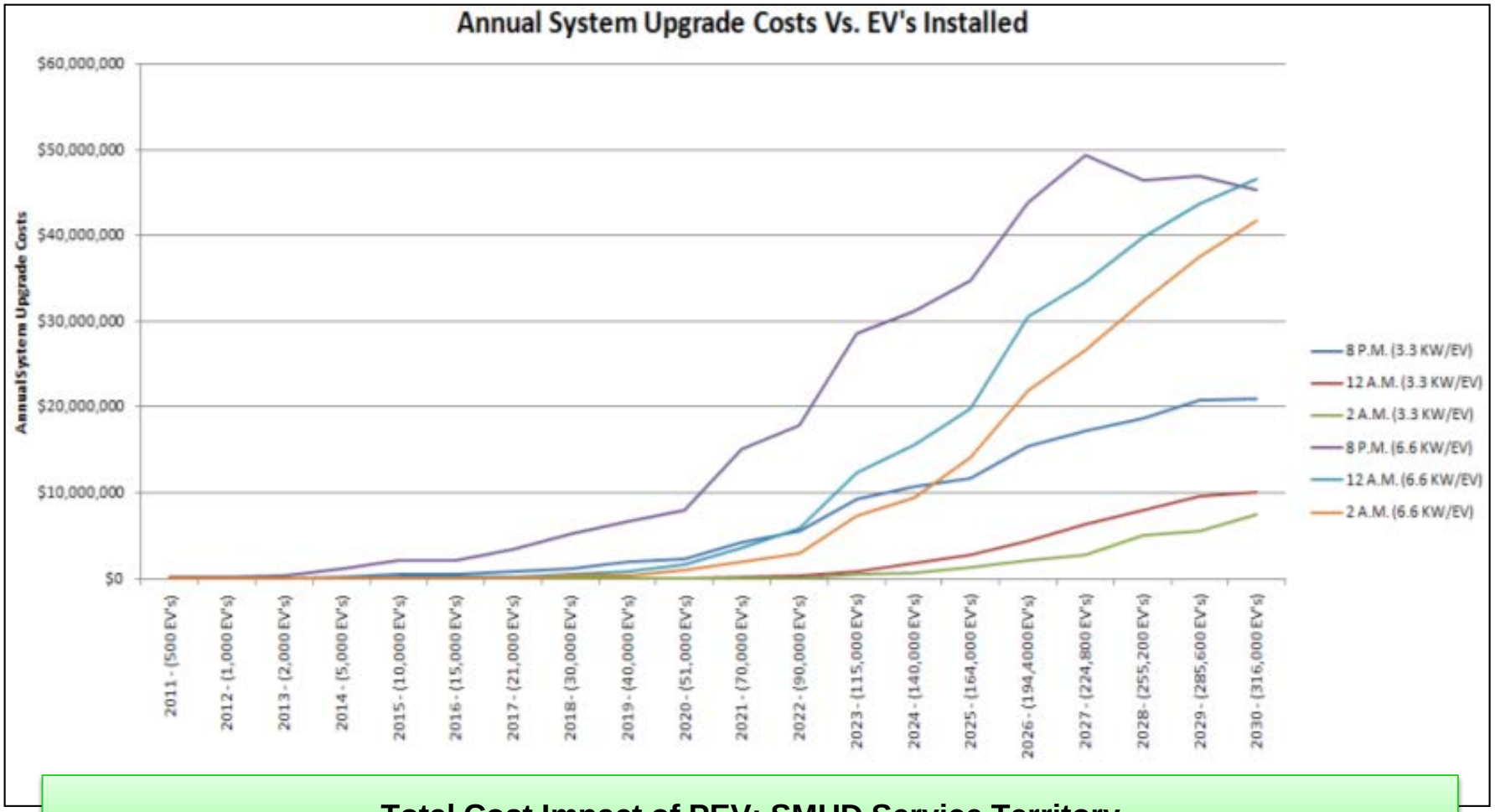
Managing Vehicle Charge Power and Time Significantly Reduces Grid Impacts

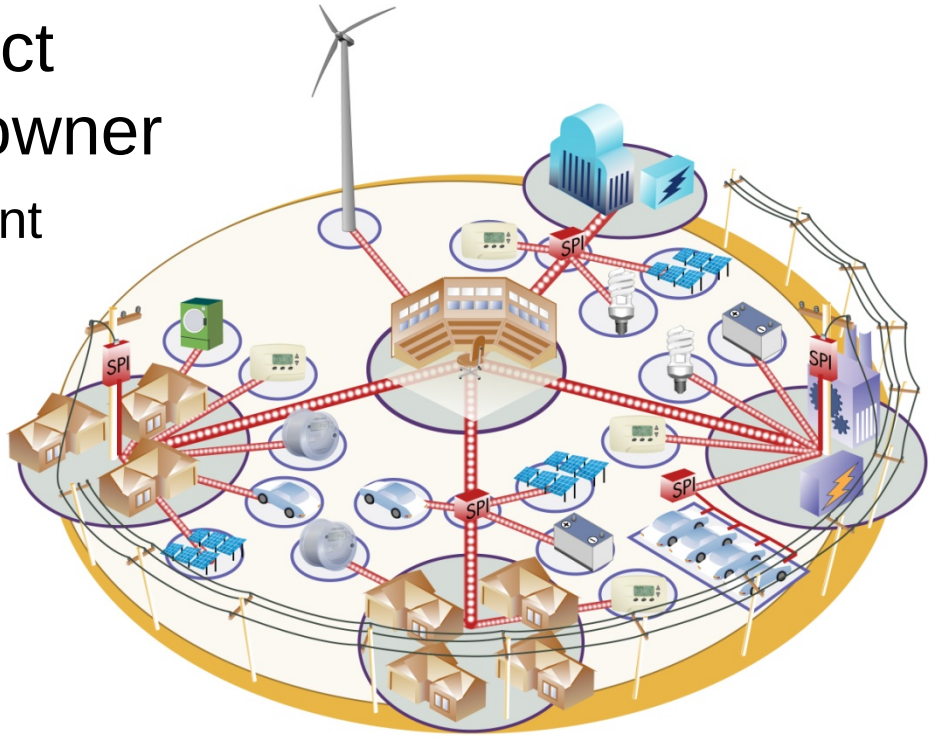


Total Cost Impact of PEV: SMUD Service Territory

Smart Charging is the Key to Reducing Grid Impacts, Long-Term Utility Operations

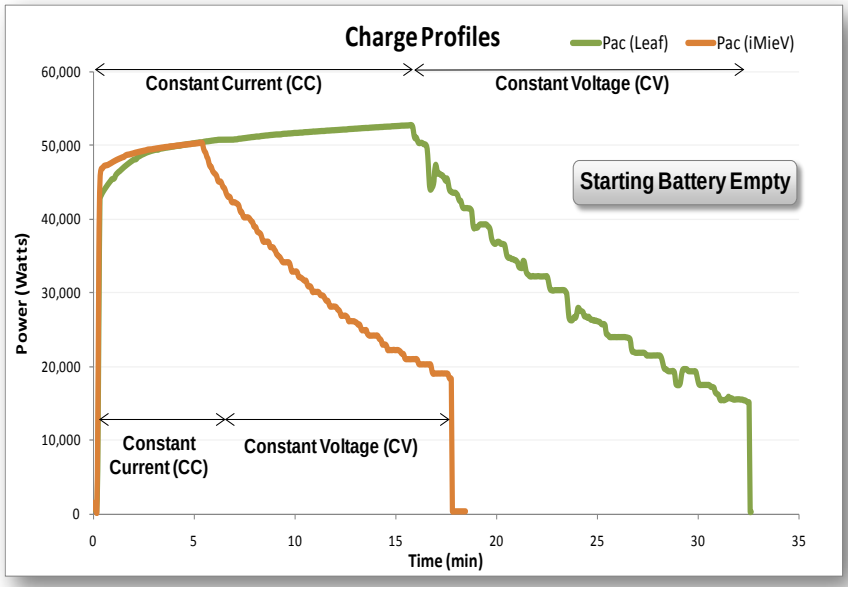
Vision – By 2015, all new PEVs can communicate to the smart grid and charging is intelligently managed

- 'Smart charging' is a compact between utility and vehicle owner
  - Low cost, scalable, and convenient
  - Minimize system impacts
- Implement with AMI, HAN, internet, telematics, etc.
- Vary time-of-day and charge power
- Uncertain outcome for necessary communications standardization (SAE J2836)

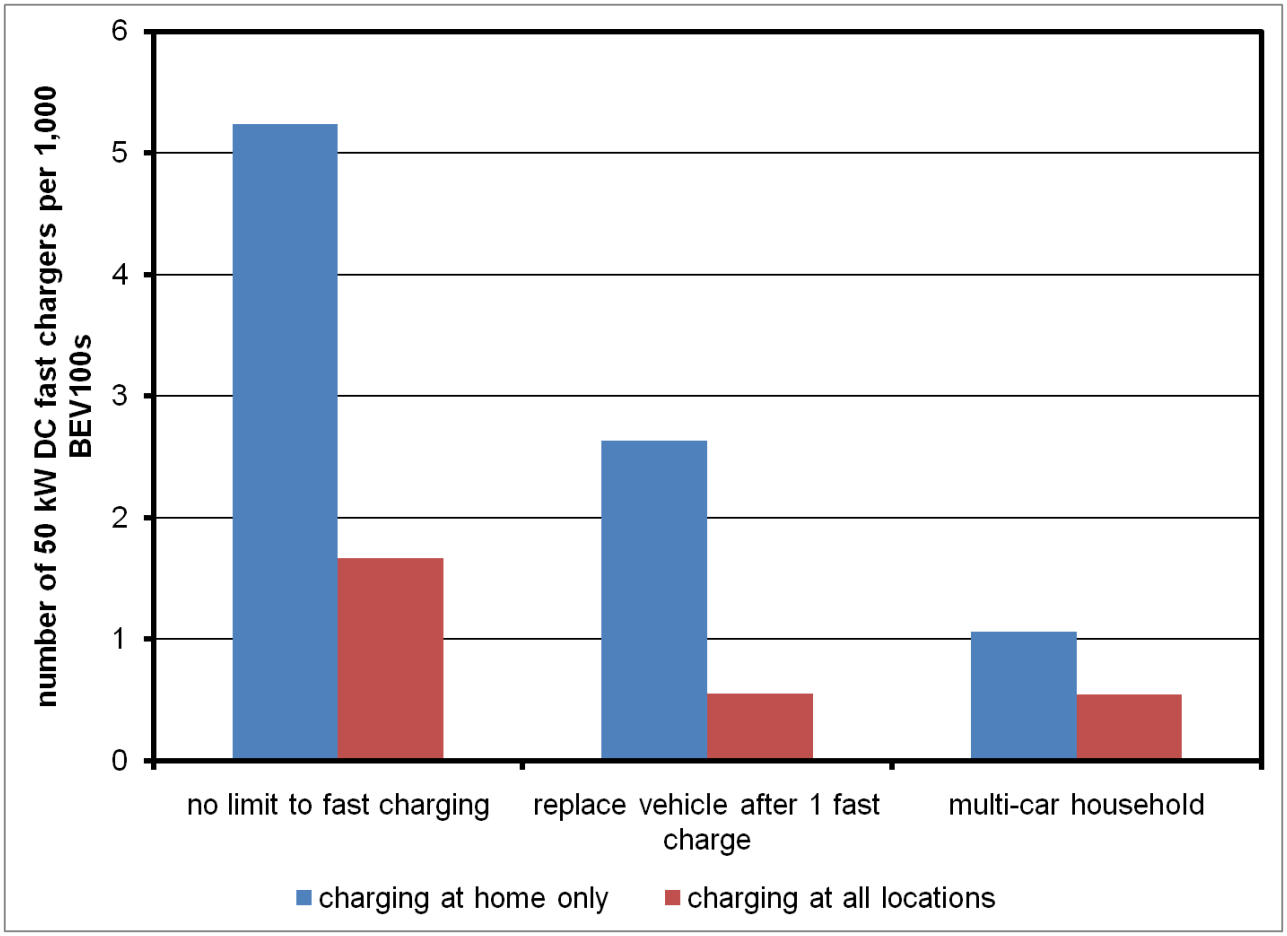


DC Fast Charging

- Likely to significantly increase customer acceptance of BEVs
  - Expect DC charging in PHEVs also
- Equipment falling in price, installation and service costs will be dominant expenses
  - Demand charges
- Uncertain how to financially sustain a significant network
- Careful planning can minimize the number of charge spots



Fast Charging – How Many?



Assuming a 50 kW DC fast charger, and 6.6 kW charging at other locations, fast charging need is relatively low: 1-5 per 1,000 BEV100s. BEVs may be ideal for multi-car households, where a vehicle replacement is available.