VEHICLE TECHNOLOGIES PROGRAM

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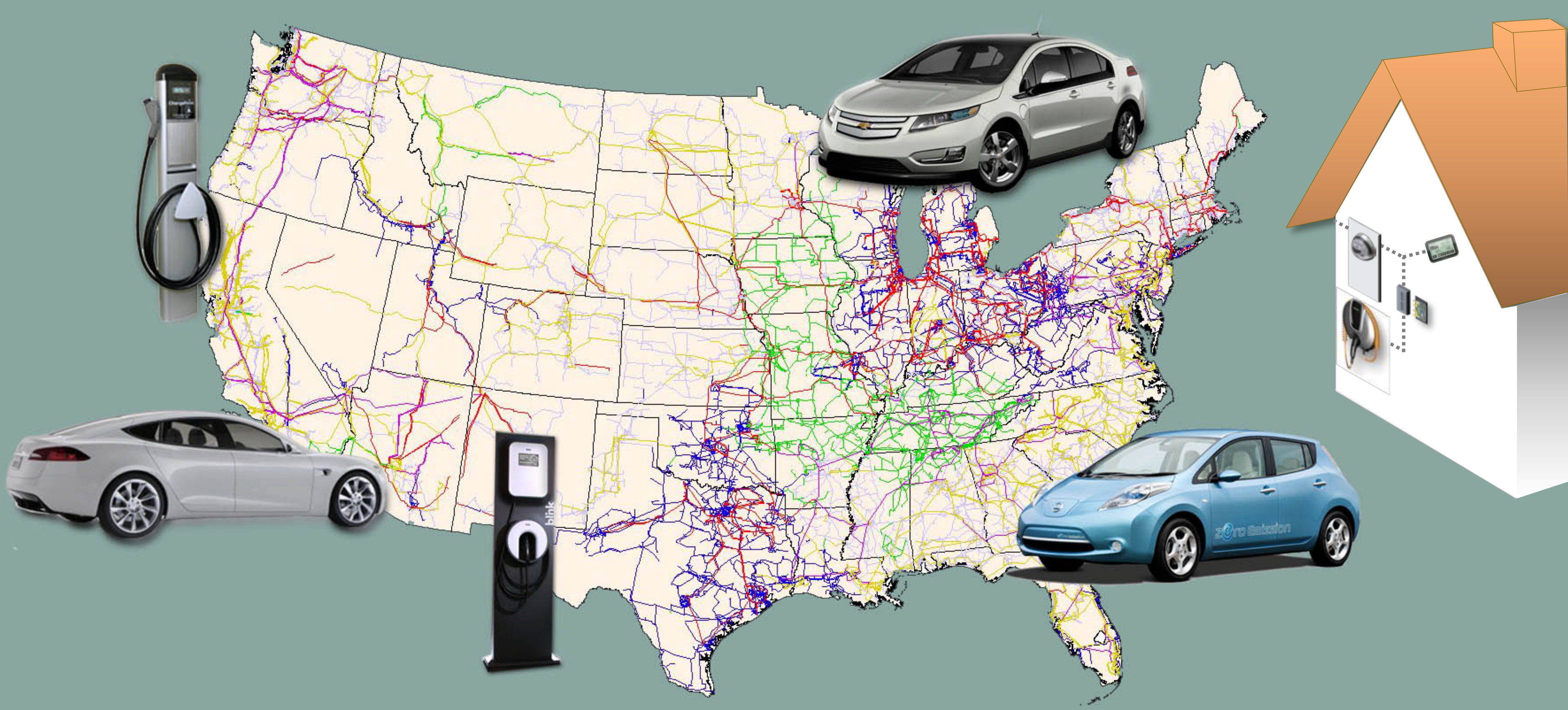

Plug-In Vehicle Operation, Fuel Economy, and Grid Connectivity

Use as a companion to Electric-Drive Vehicle Basics

Vehicle Types

Toyota Prius **Hybrid**

- "Hybrid Synergy Drive' uses both the engine and electric drive to meet power demands
- **Battery utilizes < 0.5 kWh per cycle – negligible electric range**; provides power assist (for acceleration) and captures regenerative energy (braking);
- <u>Does not plug in</u>; battery is recharged with regenerative energy and/or by the engine

Toyota Prius **Plug-in Hybrid** (pre-production)

- 'Hybrid Synergy Drive' with the same power-sharing strategy beyond the electric range
- **Larger battery (~5 kWh utilized) – 13 mi. electric range**
- Charges using 240v AC (SAE J1772 connector) or 120v AC outlet

GM Volt **Plug-in Hybrid** (aka 'Extended-Range EV')

- 'Voltec Electric Drive' uses 1 or 2 motors depending on speed in electric operation; uses both the engine and electric drive to meet power demands in hybrid operation
- **Large battery (14.4 kWh utilized) – 40 mi. electric range,** then hybrid operation; provides power assist (acceleration) and captures regenerative energy (braking);
- Charges using 240v AC (SAE J1772 connector) or 120v AC outlet

Nissan Leaf **Plug-in Electric**

- Electric drive/battery provides all motive power and captures regenerative energy (braking)
- **Very large battery (36.0 kWh utilized) – 100 mi. electric range**; substantial sensitivity to the use of accessories, driving style and terrain
- Charges using 240v AC (SAE J1772 connector) or DC fast charger (optional)

Vehicle Operation and Economy

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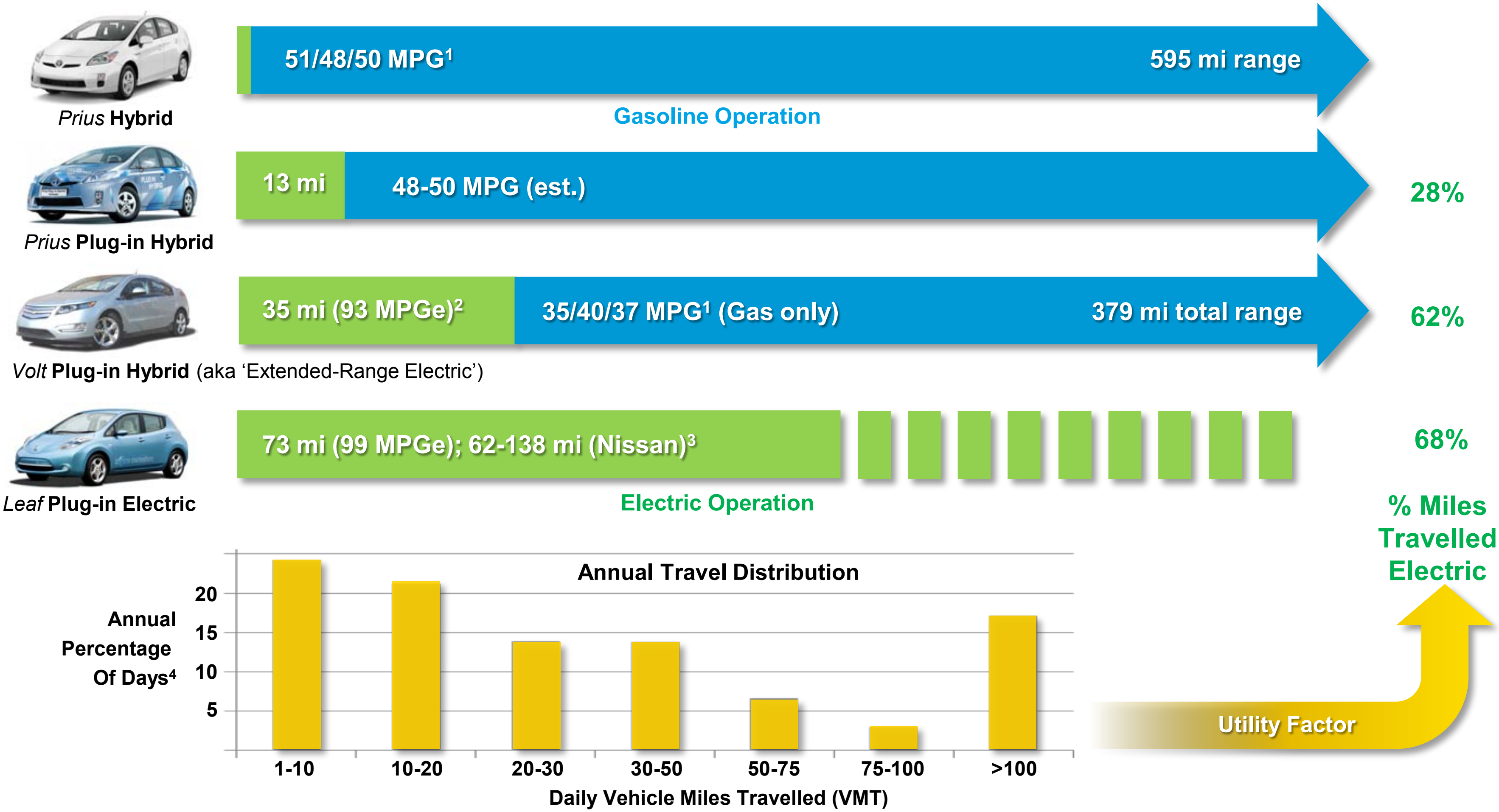

[1] EPA rated fuel economy on urban/highway/combined driving cycles
[2] MPG equivalent = combined city/highway electric energy consumption translated to fuel economy based on 33.7 kWh per gallon of gasoline
[3] 'Real world' range results by Nissan as a function of climate control, speed, driving style and load/topography
[4] Representative travel distribution; source: http://www.fhwa.dot.gov/policyinformation/pubs/pl10023/fig4_5.cfm

Charging Standards (U.S.)

Charge Method *Typical charge rates*	**Nominal Voltage/ Branch Circuit Rating**	**Charge Coupler (aka plug and receptacle)**
AC Level 1 **RESIDENTIAL** *5 mi/hour @ 1.7 kW*	**120v/20A** (15A continuous)	
AC Level 2 **RESIDENTIAL** *10 mi/hour @ 3.4 kW* **COMMERCIAL** *20 mi/hour @ 7.2 kW*	**240v/20A** (15A continuous) **240v/40A** (30A continuous)	
DC Level 2 **(Fast Charging)** **COMMERCIAL** *165 mi/hour @ 50 kW*	*Standards in process* **480 V AC, 3Ø** (supply to EVSE)	

Charge Times* Versus Method

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	Plug-in Prius	Volt	Leaf
AC Level 1 **RESIDENTIAL** *5 mi/hour @ 1.7 kW*	**2.6 hrs**	**10 hrs**	**20 hrs**
AC Level 2 **RESIDENTIAL** *10 mi/hour @ 3.4 kW* **COMMERCIAL** *20 mi/hour @ 7.2 kW*	**1.3 hrs**	**4 hrs**	**10 hrs**
DC Level 2 **(Fast Charging)** **COMMERCIAL** *165 mi/hour @ 50 kW*	**Not applicable**	**Not applicable**	**36 min**

* Approximations using the charge rate (mi/hour) and nominal electric range (13, 40 and 100 mi, respectively);
The AC Level 1 charge time for the Volt (10 hrs) is the GM estimate based on the 120v 1.2 kW charger provided as standard equipment with the vehicle

Charger Costs (U.S.)

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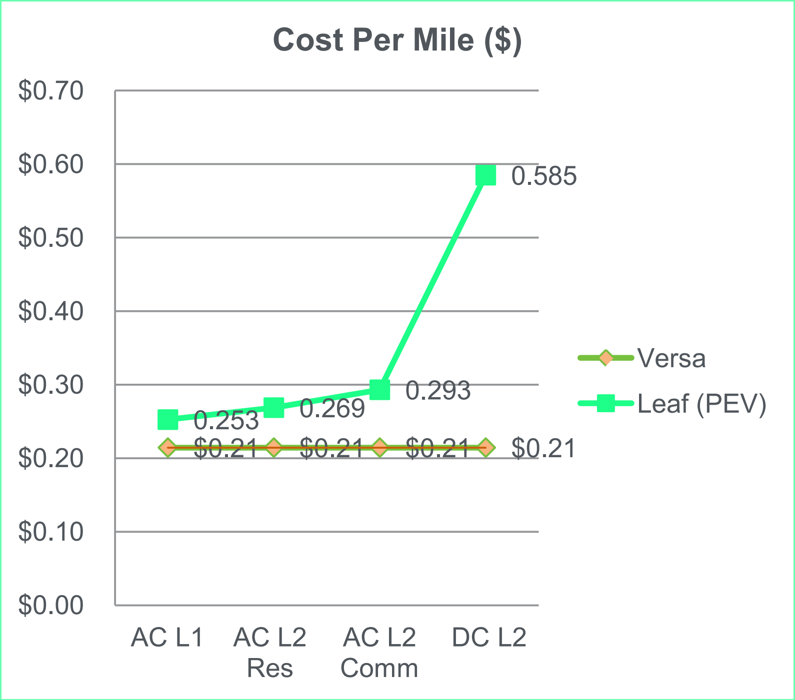
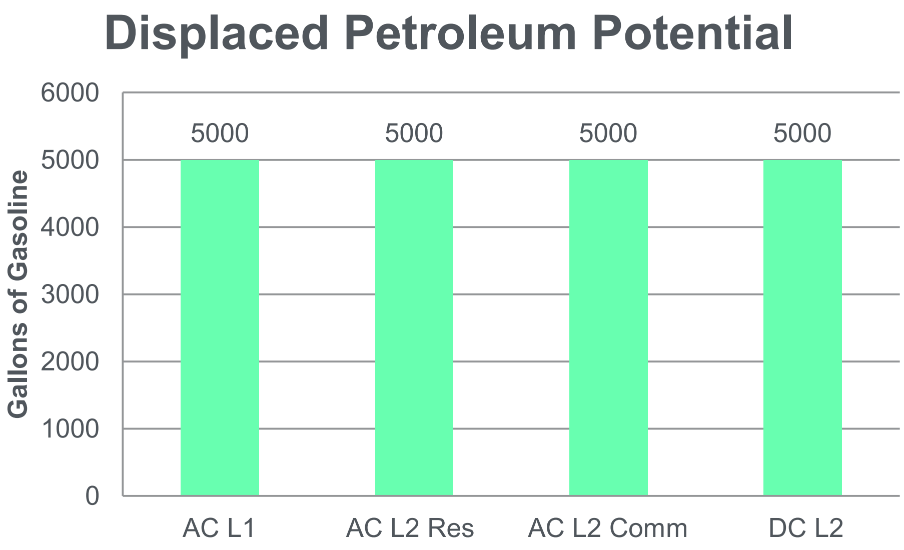
Charge Method *Typical charge rates*	Hardware Costs ($)	Installation Costs ($)
AC Level 1 **RESIDENTIAL** *5 mi/hour @ 1.7 kW*	**$0 - $125** PEV standard equipment	**$0 - $150**
AC Level 2 **RESIDENTIAL** *10 mi/hour @ 3.4 kW* **COMMERCIAL** *20 mi/hour @ 7.2 kW*	**$460-$1495** **$2500-$2950**	**$600 - $3000** **$2500 - $4500**
DC Level 2 **(Fast Charging)** **COMMERCIAL** *165 mi/hour @ 50 kW*	**$10,000-$60,000**	**$10,000-$20,000**

Cost - Benefit of Faster Charging

Nissan Leaf, 10 year vehicle lifecycle , Average Miles/Residential



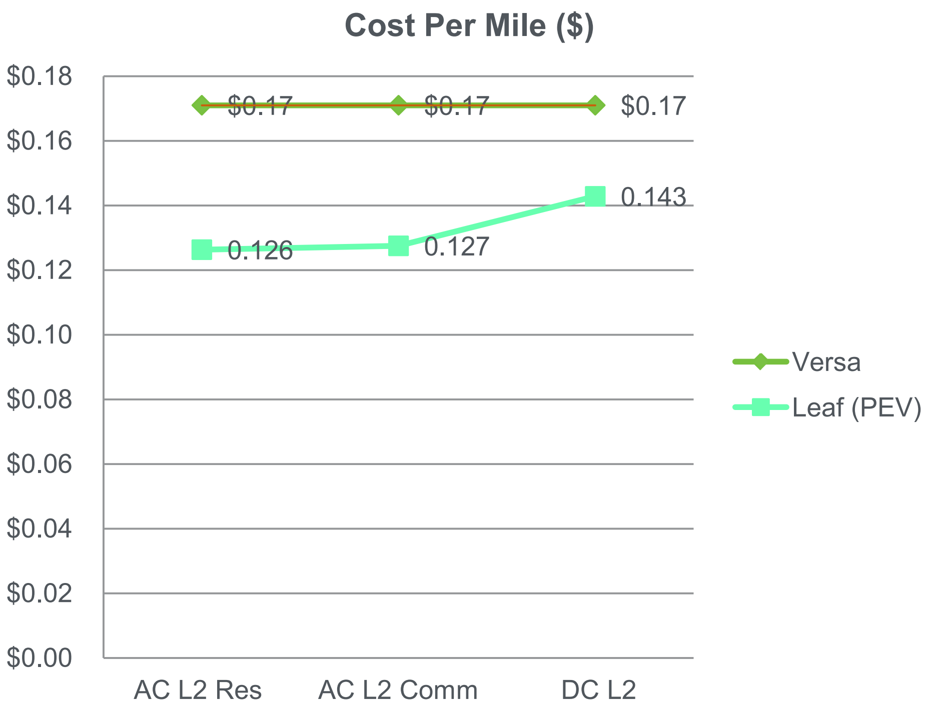


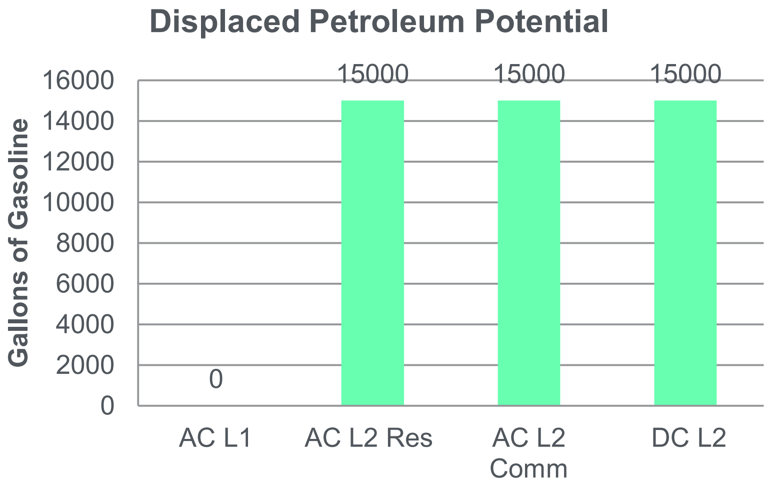
For Residential Drivers – Average miles per day ~ 42

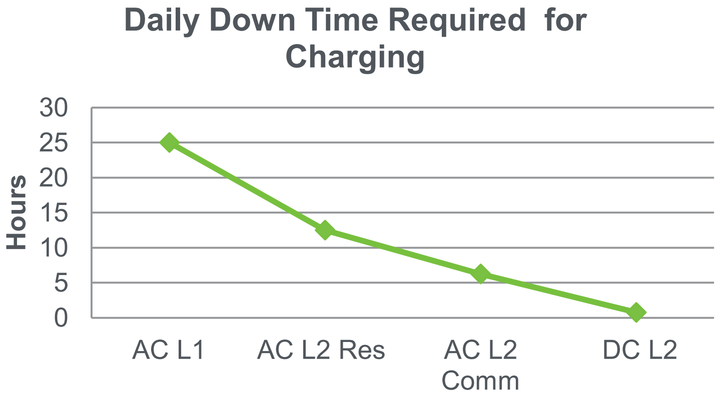
No motivation for Residential Ownership of Current Generation Commercial Fast Chargers

Cost - Benefit of Faster Charging

Nissan Leaf, 10 year vehicle lifecycle , High Miles/Commercial







For Higher Mileage Commercial Drivers ~ 125 miles per day
AC L1 Chargers cannot provide enough charge to meet daily PEV energy requirements.
Commercial Charger costs can be shared by multiple vehicles
Motivation for Commercial Fast Chargers is reduced charging time

Public EVSE Value Proposition

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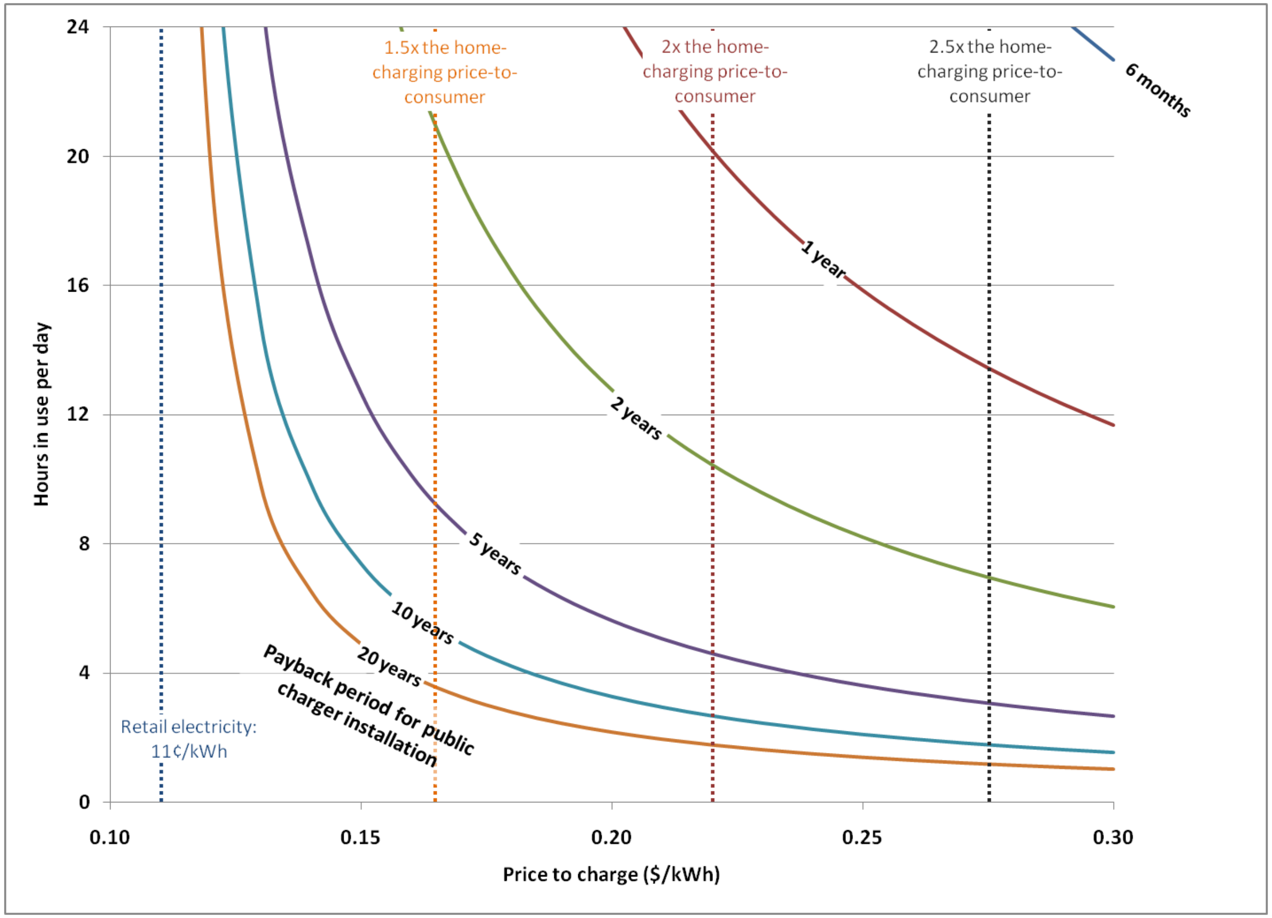
The value proposition for public EV charging infrastructure is unclear.

- EVSE must be highly utilized, and owner must charge a premium for a reasonable return (incentivizes customer to charge at home).
- New business model: host/owner relationship (flat-rate subscription charged to consumer)

Note: Electricity cost approx. equal to gasoline ($0.11/kWhr=$3.80/gallon), but about 1/3 the cost of gasoline on a cents/mile basis

Public Level 2 EVSE Payback



- *Assumes capital equipment and installation costs of $5000/unit*
- *Assumes no O&M costs, revenue sharing, etc.*

Public EVSE Value Proposition

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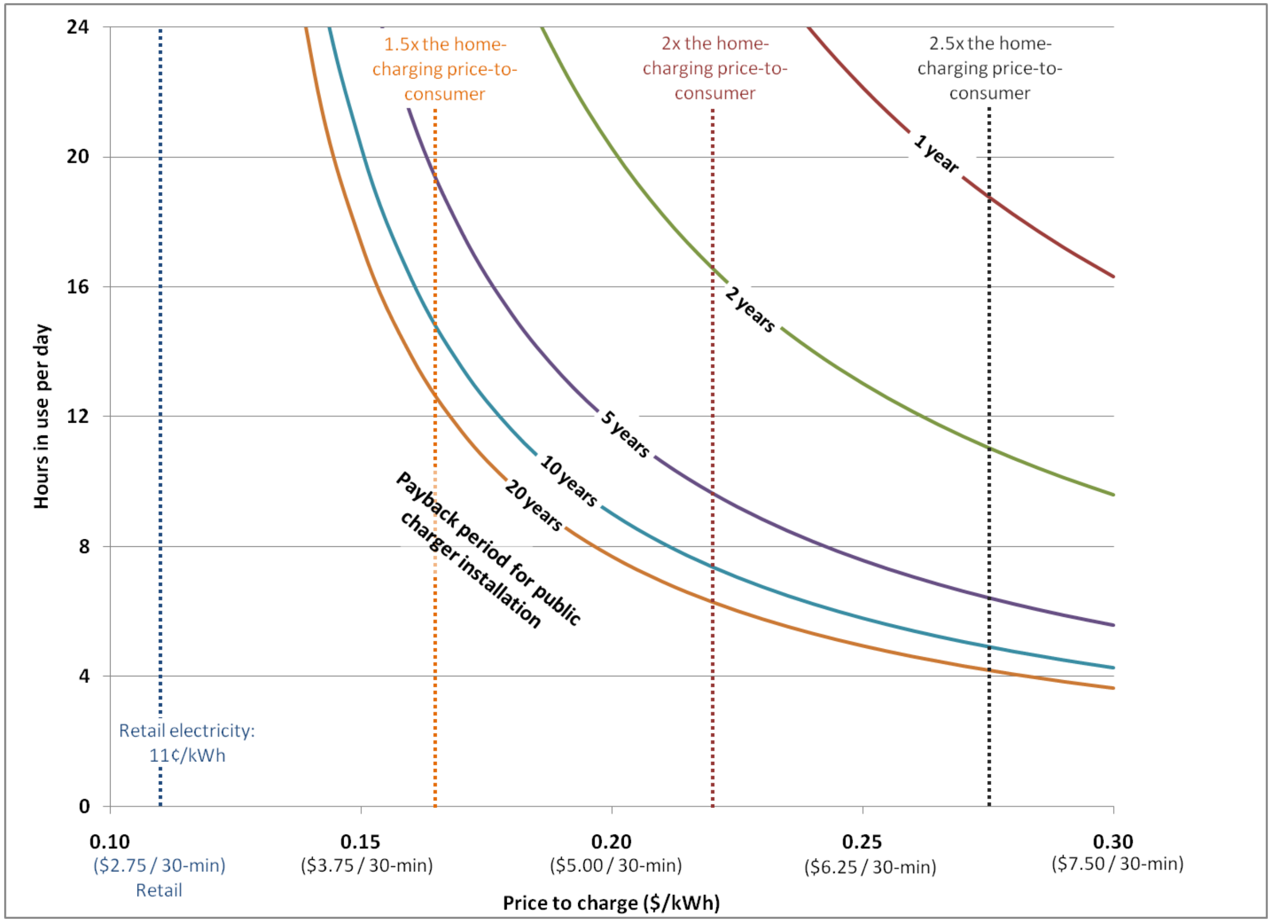
DC Fast Charging is most suitable for public infrastructure, but cost is too high.

- Installation and capital costs for 50kW EVSE is prohibitive.
- Demand charges from electric utility add to operating costs.
- Market is still developing – North American DC Fast Charge standard is not yet in place.

Public DC Fast Charge EVSE Payback



- *Assumes capital equipment and installation costs of $45,000/unit, and $700/mo utility demand charge*
- *Assumes no O&M costs, revenue sharing, etc.*

Charging Infrastructure Costs

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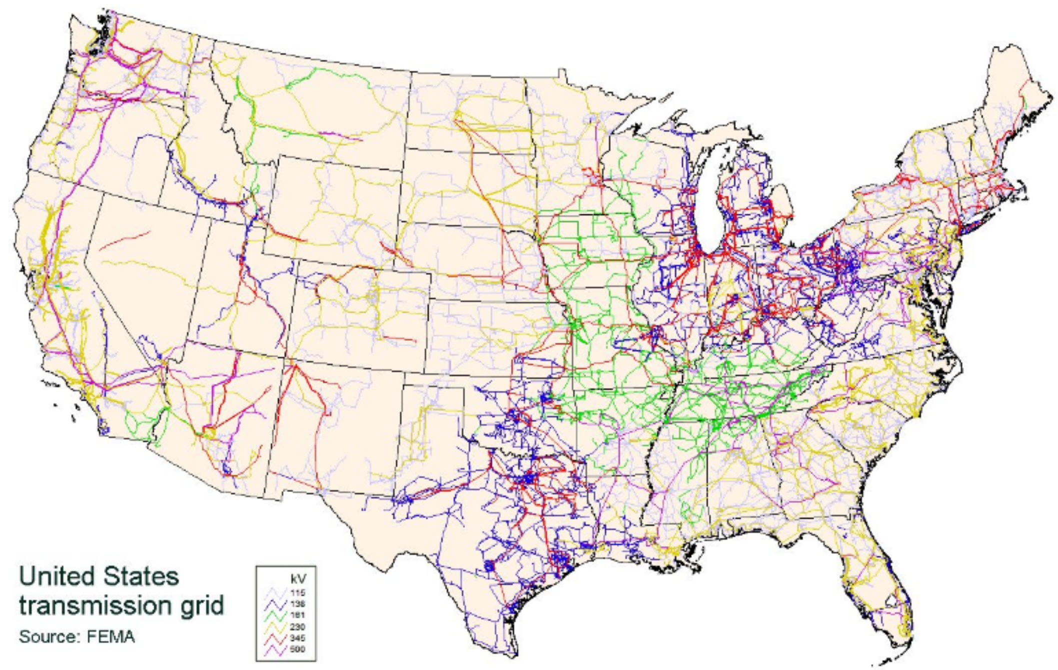
Plug-in EV's Leverage Pre-Existing Infrastructure

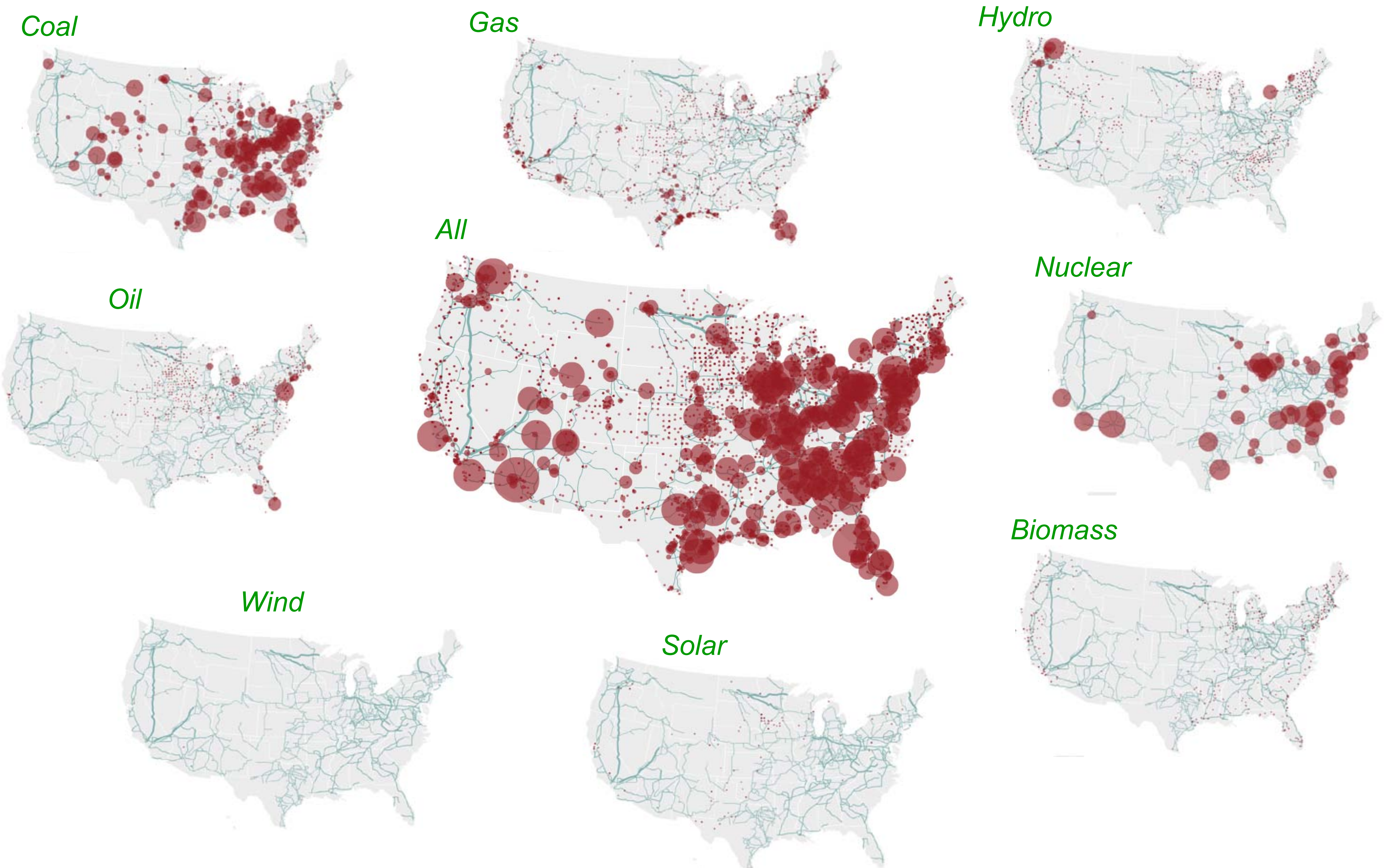
EV Chargers are the last few feet!



*US Grid is a **pre-existing** Trillion dollar energy transmission network !*

Electric Power Generation Sources

Today ‘s Generation Plants – All Types

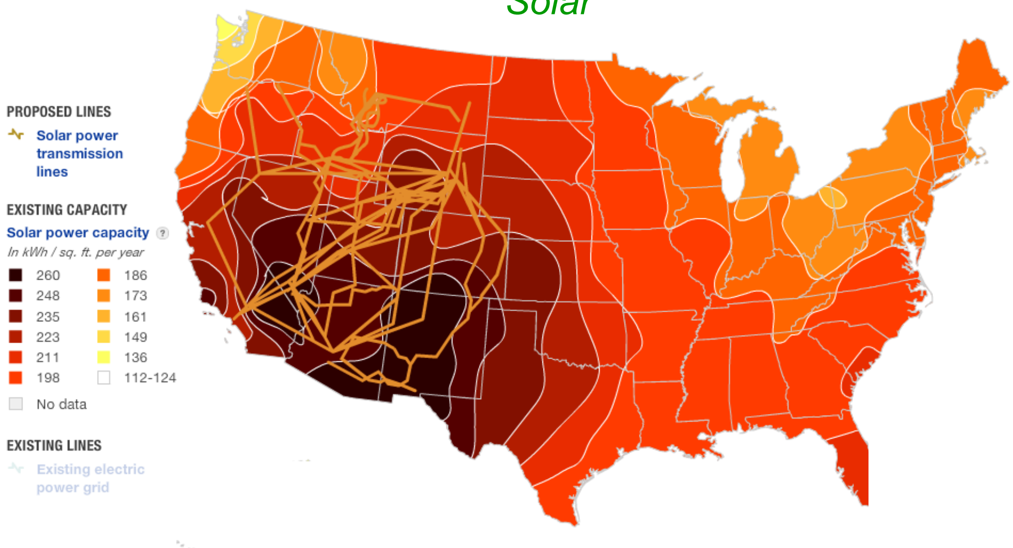


Source: www.NPR.org

Electric Power Generation Sources

Tomorrow's Generation Plants – Low GHGs

Solar



Wind

PEVs offer a practical pathway to achieve lower GHGs