VEHICLE TECHNOLOGIES PROGRAM

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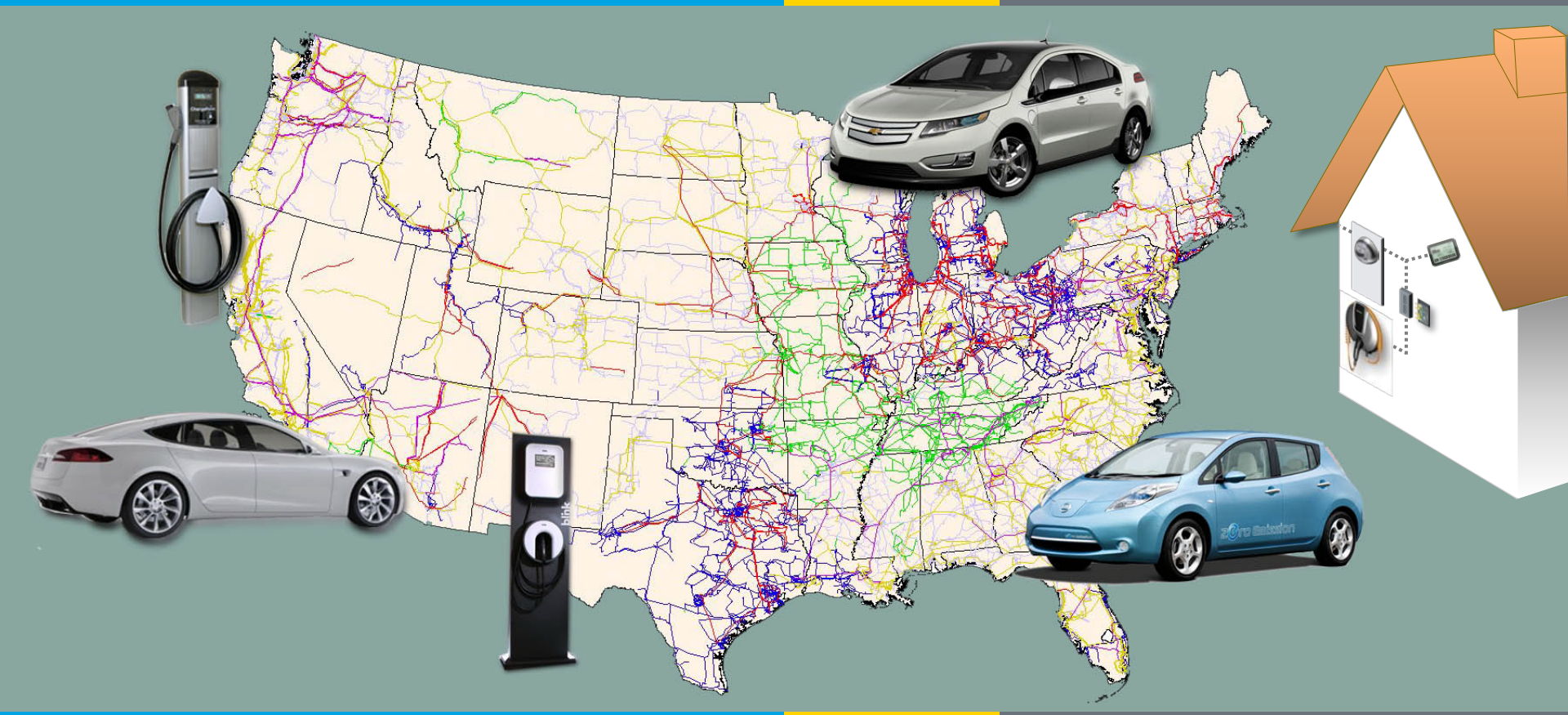

# Plug-In Vehicle Operation, Fuel Economy, and Grid Connectivity

*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);
- Does not plug in; 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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*Prius* **Hybrid**

51/48/50 MPG[1] — 595 mi range

**Gasoline Operation**

*Prius* **Plug-in Hybrid**

13 mi — 48-50 MPG (est.) — 28%

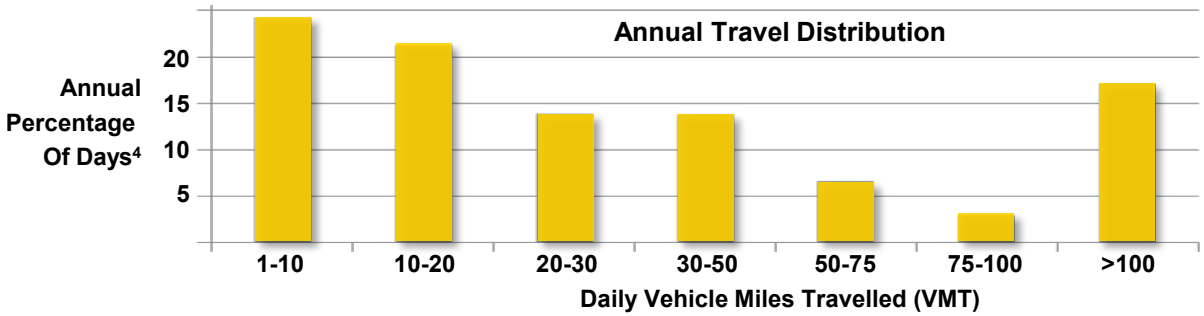
*Volt* **Plug-in Hybrid** (aka 'Extended-Range Electric')

35 mi (93 MPGe)[2] — 35/40/37 MPG[1] (Gas only) — 379 mi total range — 62%

*Leaf* **Plug-in Electric**

73 mi (99 MPGe); 62-138 mi (Nissan)[3] — 68%

**Electric Operation**




**% Miles Travelled Electric**

**Utility Factor**

[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.)

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| | Charge Method<br>*Typical charge rates* | Nominal Voltage/ Branch Circuit Rating | Charge Coupler (aka plug and receptacle) |
|---|---|---|---|
| **Residential**<br>**AC L1, AC L2** | **AC Level 1**<br>**RESIDENTIAL**<br>*5 mi/hour @ 1.7 kW* | **120v/20A**<br>(15A continuous) | |
| | **AC Level 2**<br>**RESIDENTIAL**<br>*10 mi/hour @ 3.4 kW*<br>**COMMERCIAL**<br>*20 mi/hour @ 7.2 kW* | **240v/20A**<br>(15A continuous)<br>**240v/40A**<br>(30A continuous) | |
| **Commercial**<br>**AC L2, DC L2** | **DC Level 2**<br>**(Fast Charging)**<br>**COMMERCIAL**<br>*165 mi/hour @ 50 kW* | *Standards in process*<br>**480 V AC, 3Ø**<br>(supply to EVSE) | |

# Charge Times* Versus Method

| | | Plug-in Prius | Volt | Leaf |
|---|---|---|---|---|
| | | | | |
| Residential AC L1, AC L2 | **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 |
| Commercial AC L2, DC L2 | **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

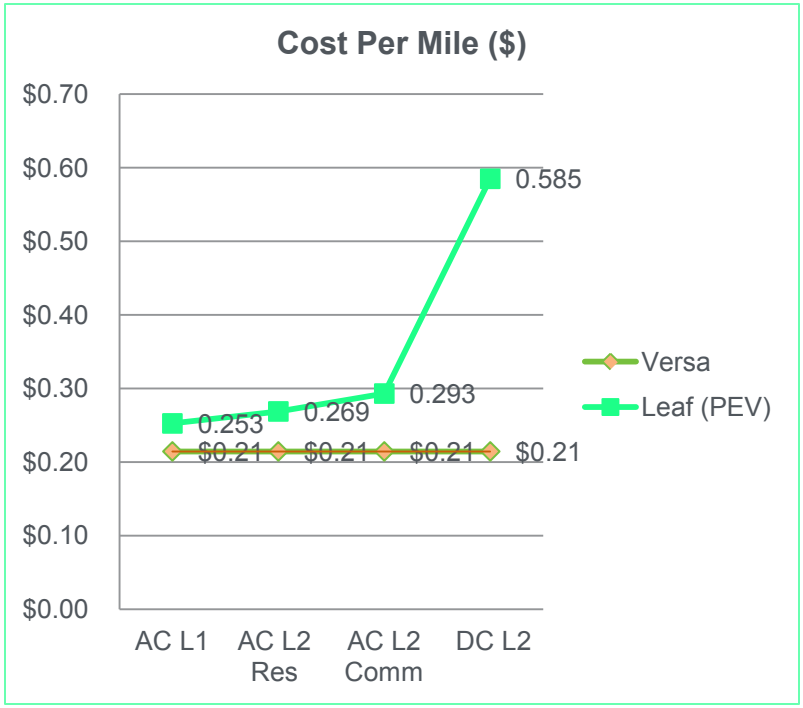
# Charger Costs (U.S.)

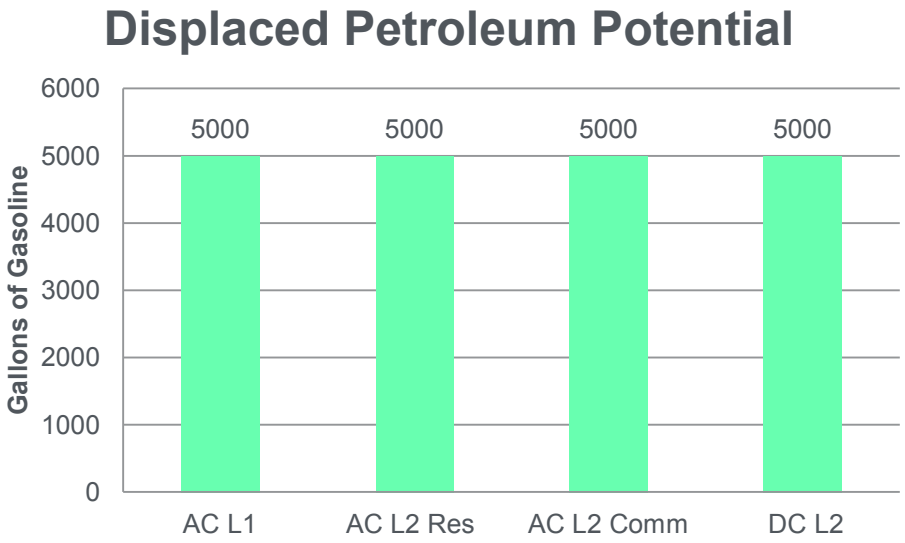
| | Charge Method<br>*Typical charge rates* | Hardware Costs ($) | Installation Costs ($) |
|---|---|---|---|
| Residential AC L1, AC L2 | **AC Level 1**<br>**RESIDENTIAL**<br>*5 mi/hour @ 1.7 kW* | **$0 - $125**<br>PEV standard equipment | **$0 - $150** |
| Residential AC L1, AC L2 | **AC Level 2**<br>**RESIDENTIAL**<br>*10 mi/hour @ 3.4 kW* | **$460-$1495** | **$600 - $3000** |
| Commercial AC L2, DC L2 | **COMMERCIAL**<br>*20 mi/hour @ 7.2 kW* | **$2500-$2950** | **$2500 - $4500** |
| Commercial AC L2, DC L2 | **DC Level 2**<br>**(Fast Charging)**<br>**COMMERCIAL**<br>*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

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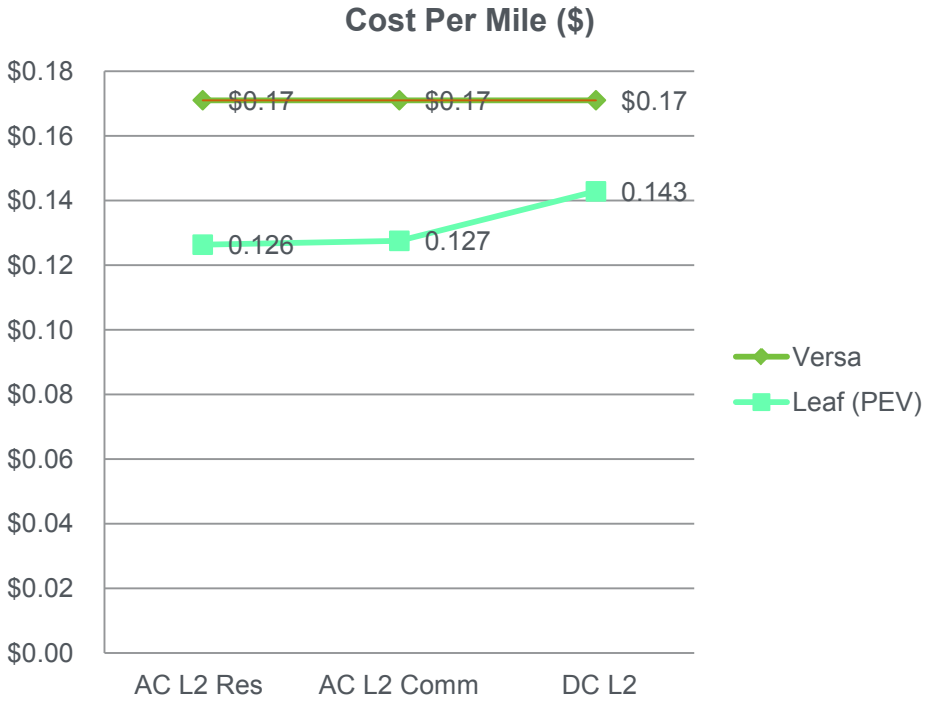


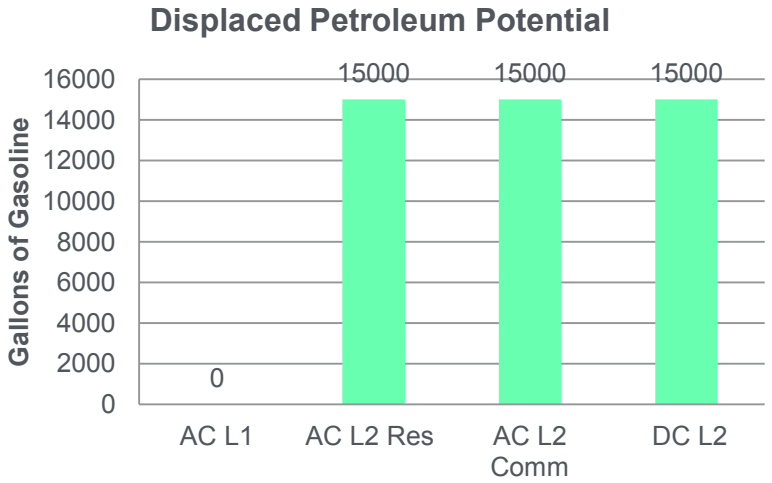


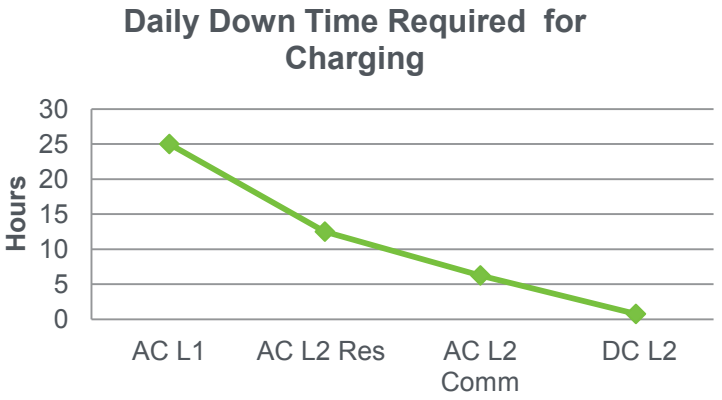


**For Higher Mileage Commercial Drivers ~ 125 miles per day**
**AC L1 Chargers cannot provide enough charge to meet daily PEV energy requirements.**
**Commercial Charger costs can be shared by multiple vehicles**
**Motivation for Commercial Fast Chargers is reduced charging time**

# Public EVSE Value Proposition

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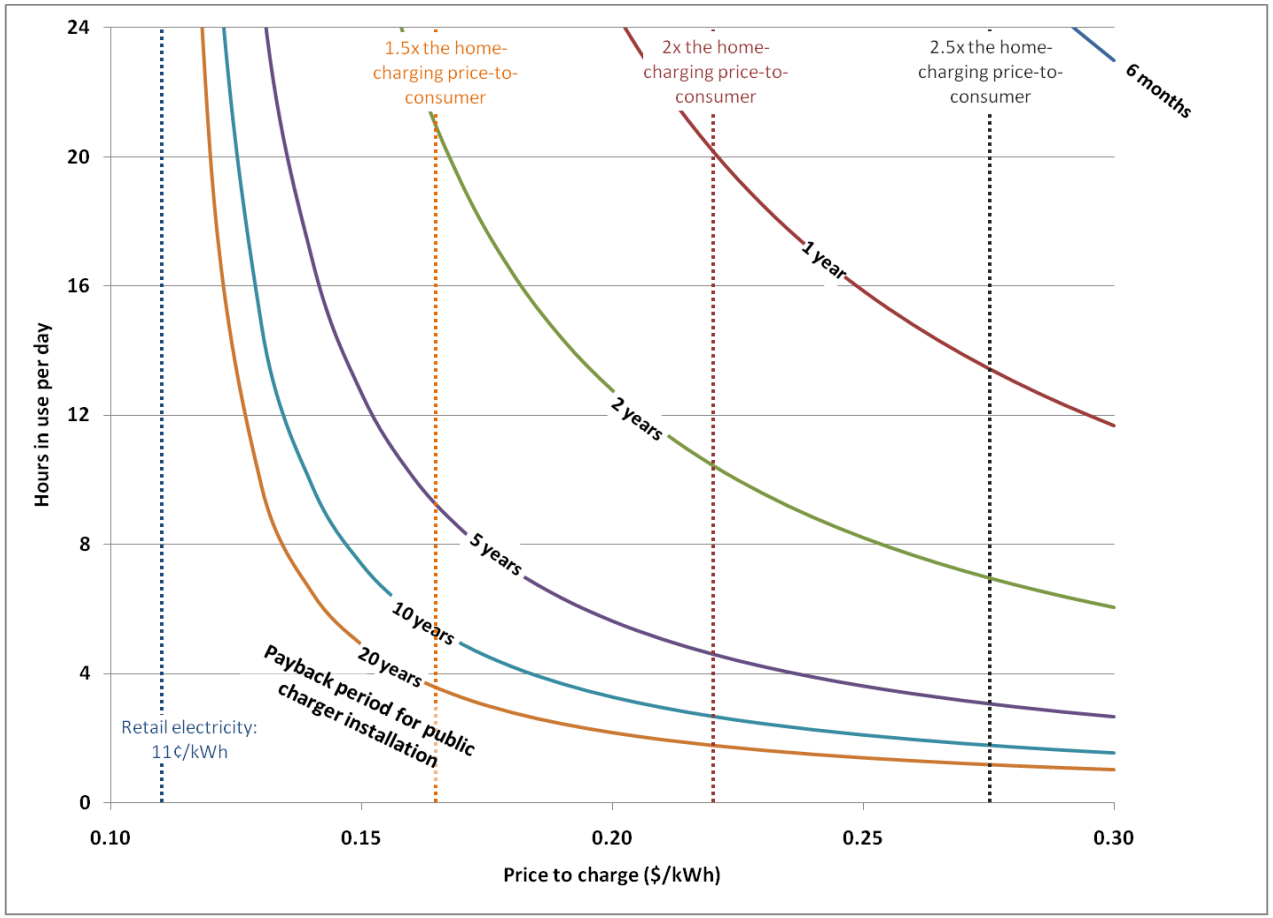
***The value proposition for public EV charging infrastructure is unclear.***

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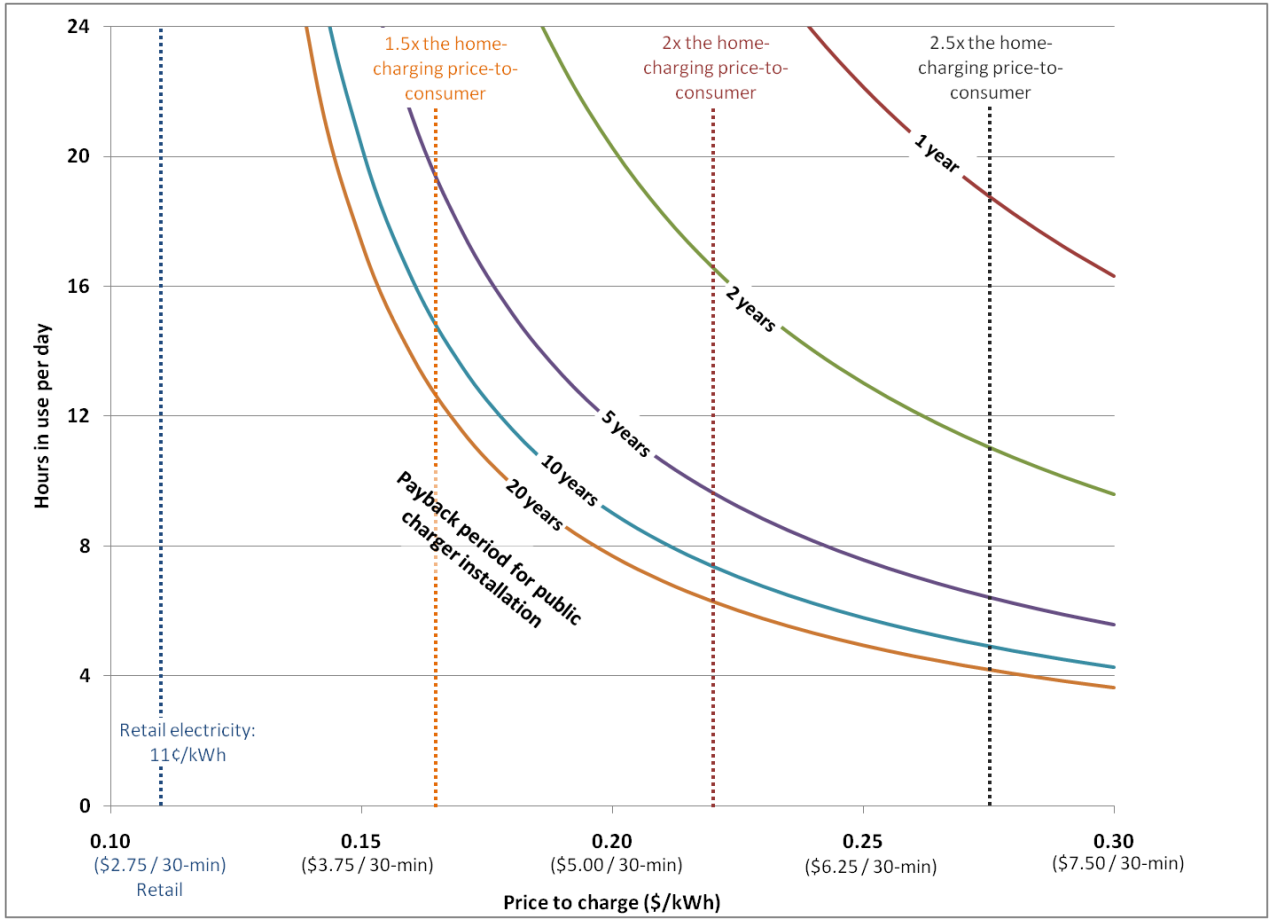
***DC Fast Charging is most suitable for public infrastructure, but cost is too high.***

- 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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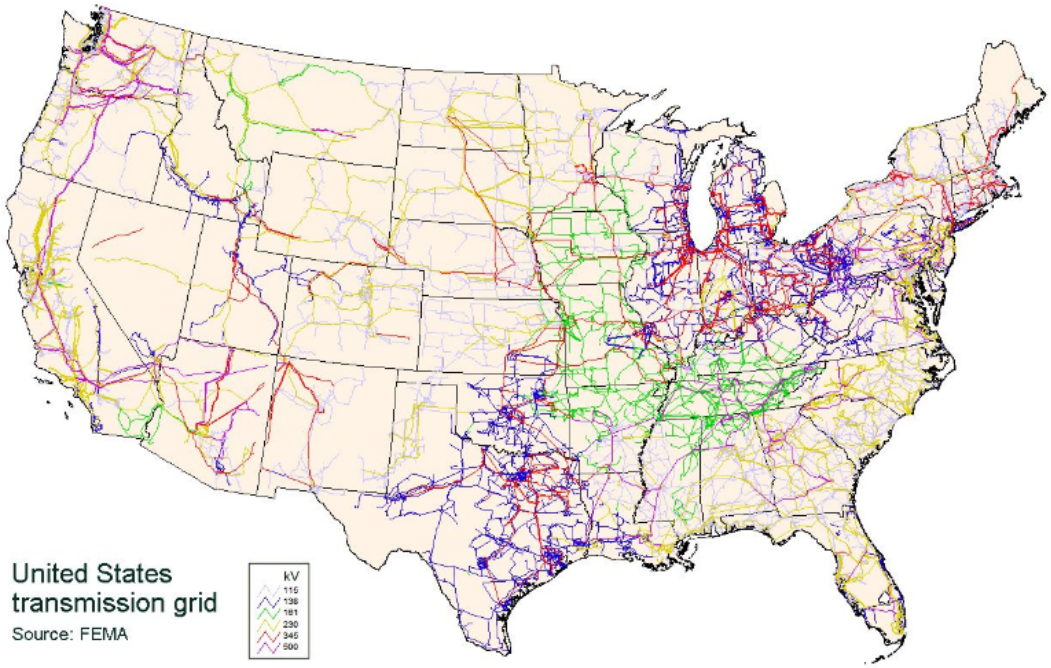
## Plug-in EV's Leverage Pre-Existing Infrastructure

***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*

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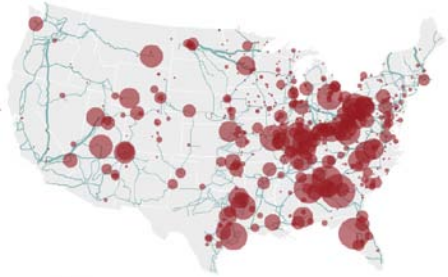
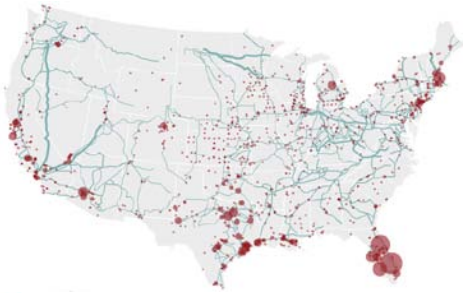
*Coal*

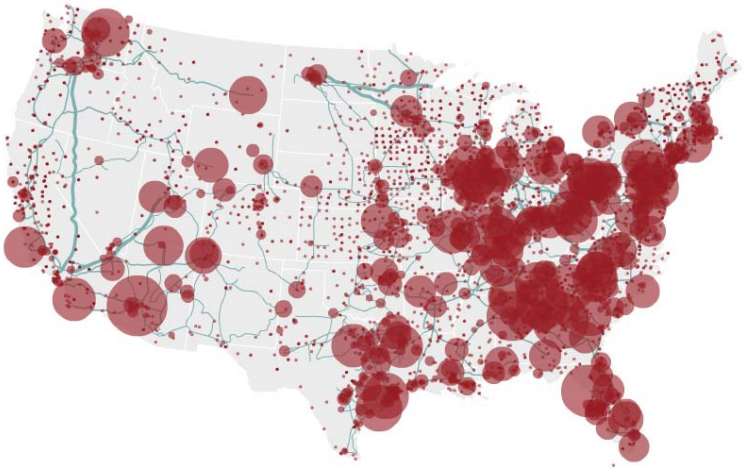


*Gas*

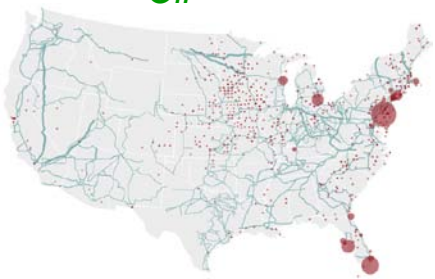


*Hydro*

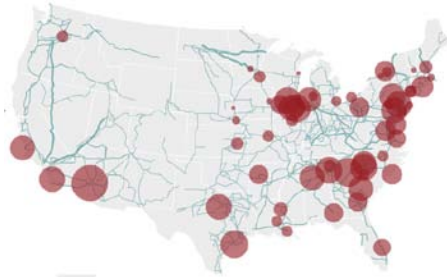
*All*



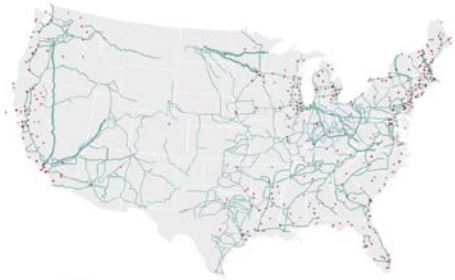
*Oil*



*Nuclear*



*Biomass*



*Wind*

*Solar*

Source: www.NPR.org

# Electric Power Generation Sources

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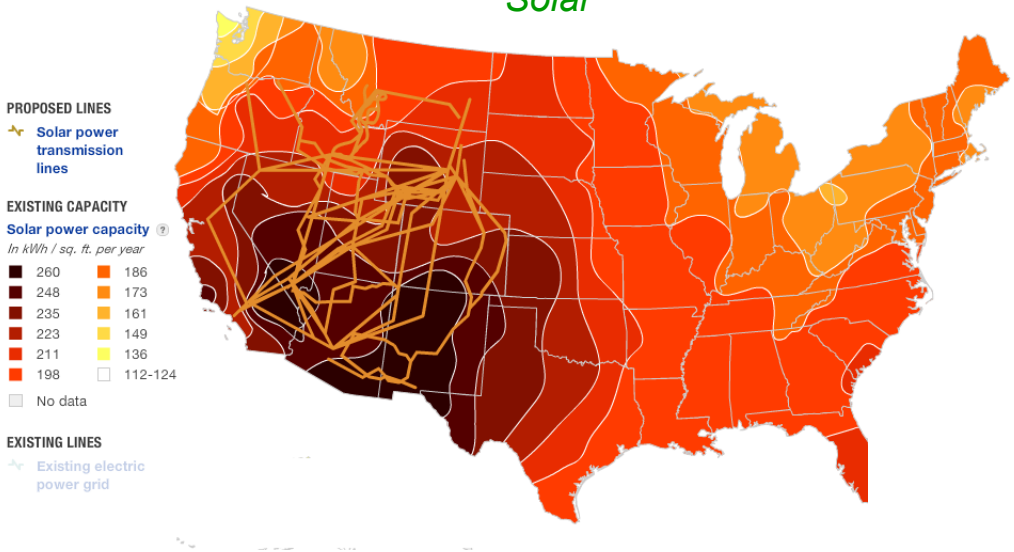
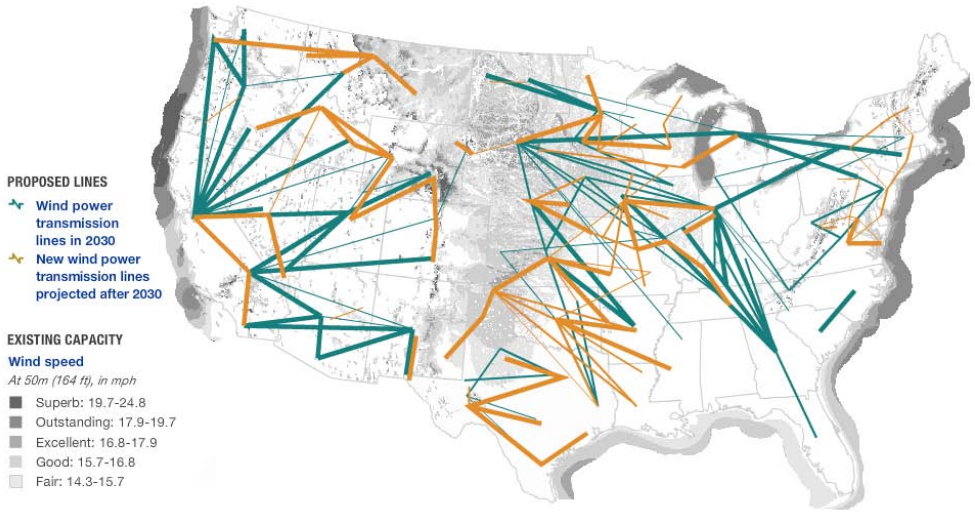
## *Tomorrow's Generation Plants – Low GHGs*

*Solar*




*Wind*




***PEVs offer a practical pathway to achieve lower GHGs***