Plug-in Realities: Charging Ahead from the 1900s to the 2000s

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1900s Markets Were: Where Garages Were for Personal Vehicles; Slow MPH Urban Delivery

- **(Midwestern) cities with lower density had higher EV car share** – houses, more new construction
- **New York was the first city to lose all personal use EVs** (multifamily, long commutes, hills)
- **New York City was the most successful location for truck fleet EVs by far** (slow average speed, many customers, large fleets, long hours, used available range)
- **Taxi fleets were also tried** (slow average speed, high value for clean and quiet)
- **Increasing power and speed of gasoline killed the EV.**

- See D. J. Santini: http://www.intechopen.com/articles/show/title/plug-in-electric-vehicles-a-century-later-historical-lessons-on-what-is-different-what-is-not-

Electrification spans most vehicle classes…

Pure EVs

Light

Heavy

Plug In Hybrids


Tesla Roadster


Smart ED


Coda Automotive


Smith Edison


Navistar EV


BMW Mini E


Ford Focus BEV


Nissan Leaf


EVI Truck


Smith Newton


Mitsubishi iMiEV


Ford Transit Connect


Think EV


Toyota Prius PHEV


Ford C-Max Energi PHEV


Bright Automotive


Azure Dynamics Step Van


Azure Dynamics Refrigerator Truck


Fisker Karma EREV


Chevy Volt EREV


Balquon HD Truck


Odyne HEV Bucket Truck

Operational Attributes and Costs

kWh/mi on Fuel Economy.gov is Only Available on Pages Specific to Plug-ins

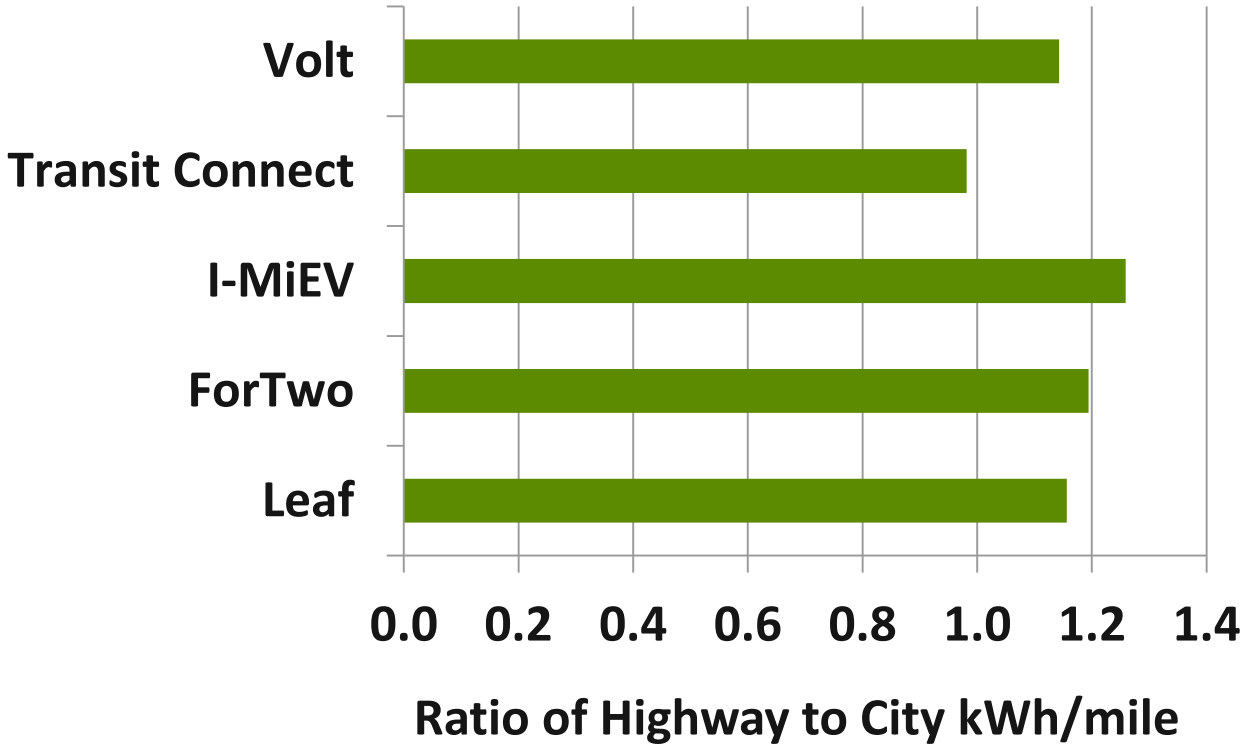
- Electric Vehicles
  - http://www.fueleconomy.gov/feg/evsbs.shtml
  - Currently rated vehicles are:
    - 2011 Nissan Leaf (5 passengers, 73 mi. range)
    - 2011 smart fortwo electric (2 passengers, 63 mi.)
    - 2012 Mitsubishi i-MiEV (4 passengers, 62 mi.)
    - 2012 Azure Dynamics Transit Connect (cargo van, 56 mi.)
- Plug-in Hybrids and Extended Range Electrics
  - http://www.fueleconomy.gov/feg/phevsbs.shtml
  - Currently rated vehicles are:
    - 2011 and 2012 Chevrolet Volt (4 passengers, 35 mi. range)

What Consumer Uses Do Attributes and Testing of Hybrids and Plug-ins Imply?

- Electric drive vehicles should be placed where driving speeds vary, but where exactly?
- Driver behavior affects amount of energy used (i.e. acceleration and top speed) and recovered (regenerated during deceleration).
- One way or another, electric drive eliminates inefficient* combustion of fuels, which is worst in variable speed driving and idling.

* aside from cabin heating

For Light Vehicles, DOE/EPA Fuel Economy.gov kWh/100 Mile Predictions Imply Faster Depletion on the Highway, with Relatively Little kWh/mi Increase



Source: Computations from data on www.fueleconomy.gov

KY Experience Demonstrates Choice of Route and Driver Training are Important

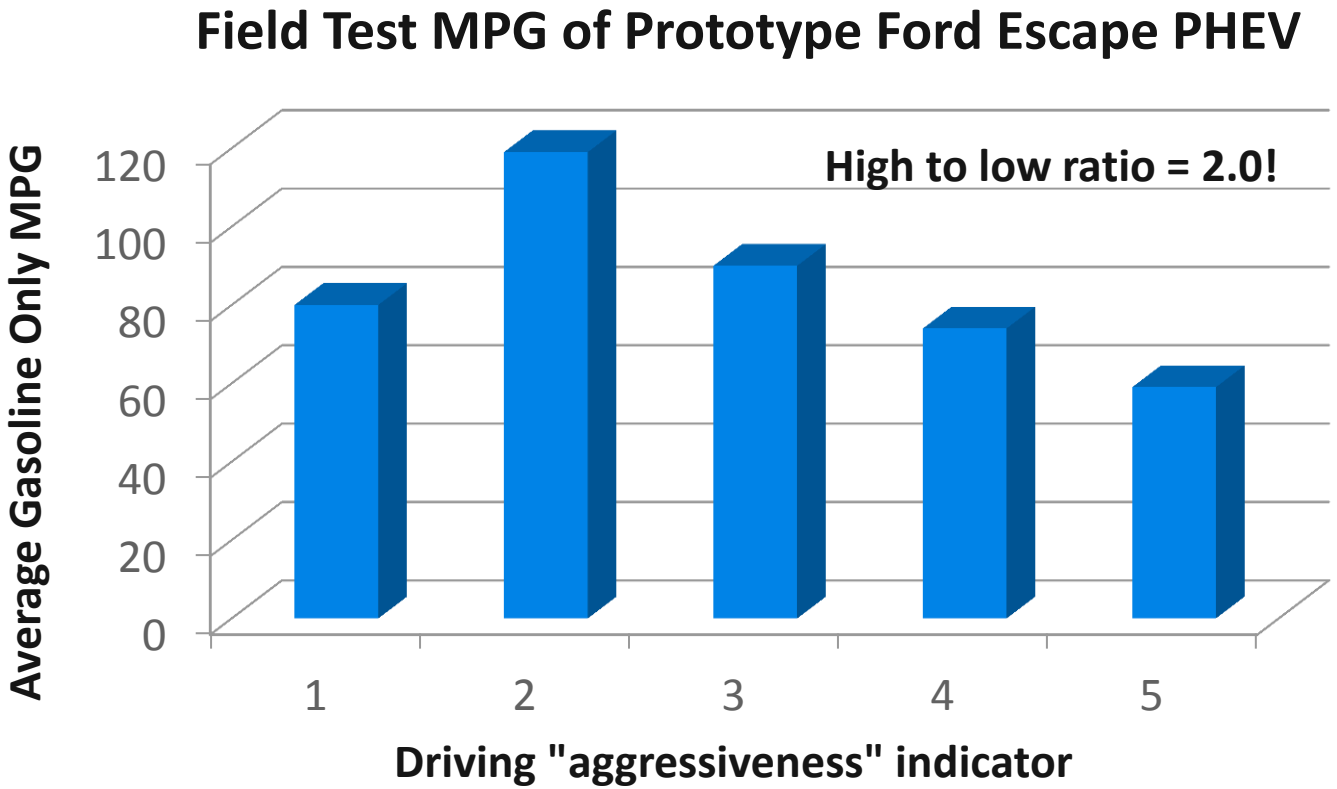
Statewide, for 125 hybrid buses, the average hybrid bus fuel efficiency is 9.65 miles per gallon, three miles per gallon higher than the baseline fuel efficiency.

But Pike County Schools, the largest fleet, gets 11.6 mpg via driver education & careful route placement of its 37 HEV buses, est. 29%* better than other 88.

* based on assumption of same miles per bus (other 88 buses must be below average)

Sources: http://kycleanfuels.blogspot.com/2011/09/hybrid-electric-school-buses-in.html;

Escape PHEV Tests Imply a "Sweet Spot"— Driving *Could be* Too "Gentle". Deceleration Rate & Frequency Affect Regeneration Savings.



Deceleration frequency is mostly related to the route; rate is under driver control
Hint: coasting deceleration does not regenerate energy.

Source: http://avt.inl.gov/pdf/phev/FordEscapeARVMonthlyReportAllNov09-Aug11.pdf.

Beware of EV Averages: EV Range is *Far* More Variable than for Gas, Diesel, HEV, PHEV, EREV

Nissan estimated different Leaf range results vs. speed, temp.

Hours to battery depletion have been computed.

Cruise, steady 38 mph, 68 degrees, 138 miles, 3.6 hrs.

City traffic, avg. 24 mph, 77-degrees, 105 miles, A/C off, 4.4 hrs.

Stop and go, avg. 15 mph, 14 degrees, heater on, 62 miles, 4.1 hrs.

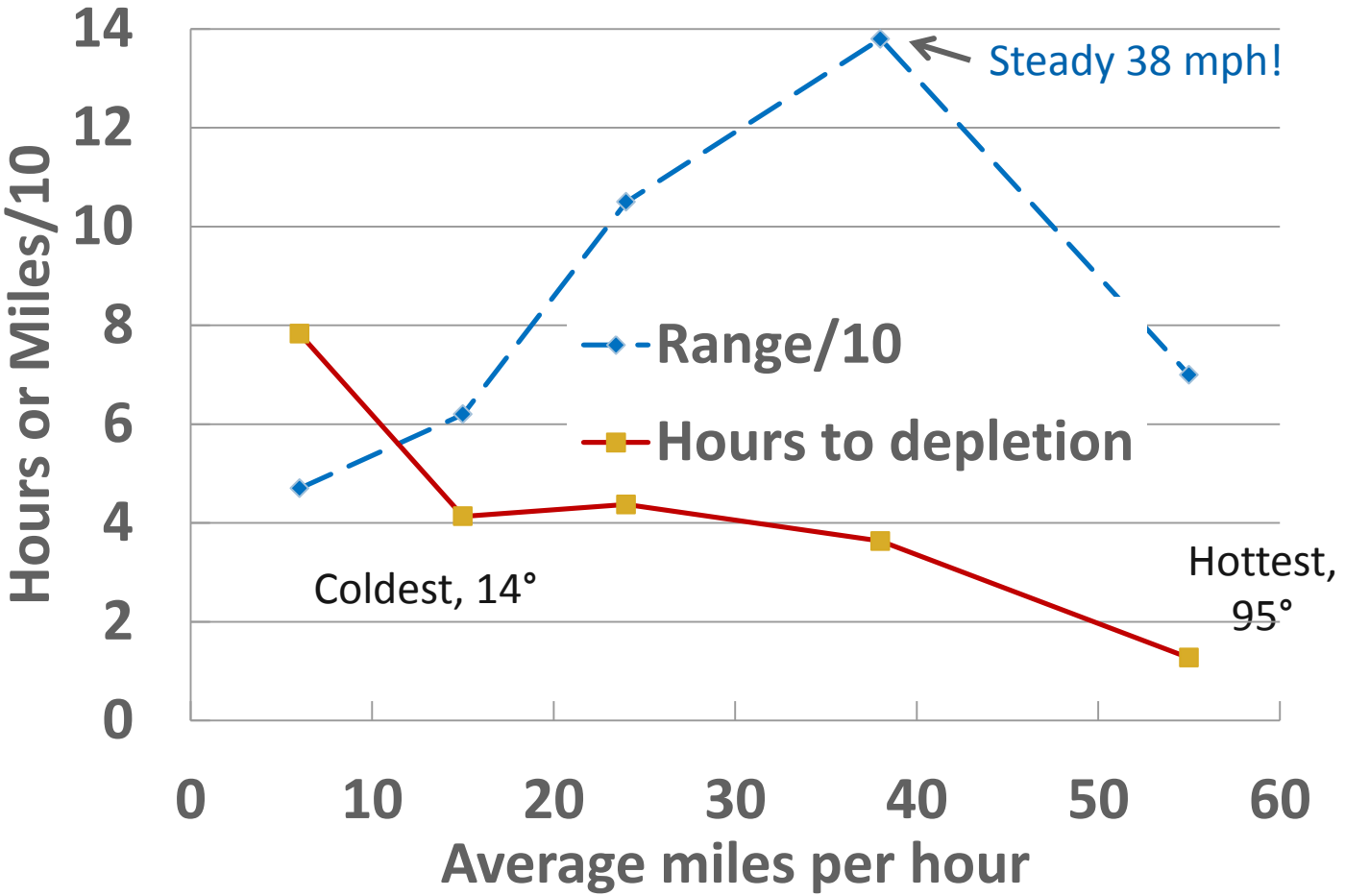
Heavy stop-and-go, avg. 6 mph, 86 degrees, A/C on, 47 mi., 7.8 hrs.

Highway, avg. 55 mph, 95 degrees and A/C on, 70 miles, 1.3 hrs.

Notice: no mention of hills, passenger & luggage, snowstorms!

http://green.autoblog.com/2010/06/14/nissan-pegs-leaf-range-between-47-and-138-miles-individual-resu/

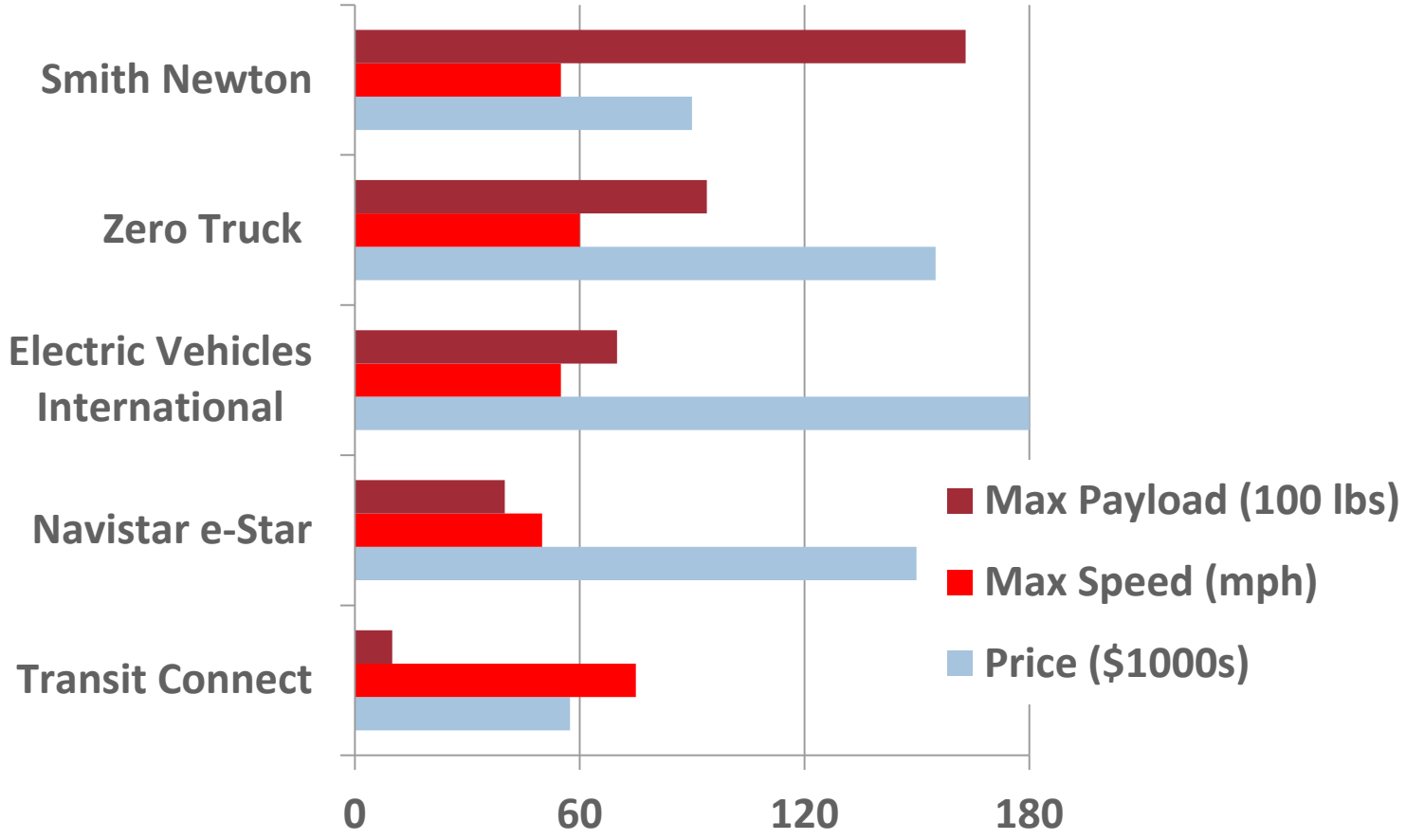
Peak Range vs. Hours of Service from Nissan's Leaf Values Imply Different "Sweet Spots"



Note: The "real world" high to low range ratio is 2.2 (105/47)

http://green.autoblog.com/2010/06/14/nissan-pegs-leaf-range-between-47-and-138-miles-individual-resu/

EV Trucks are Medium & Light, Expensive, Only Fast Enough for Intra-Urban Use



Source: Long, M. *Looking at Electric Trucks*. Light and Medium Truck, May 2011 pp. 12-15.

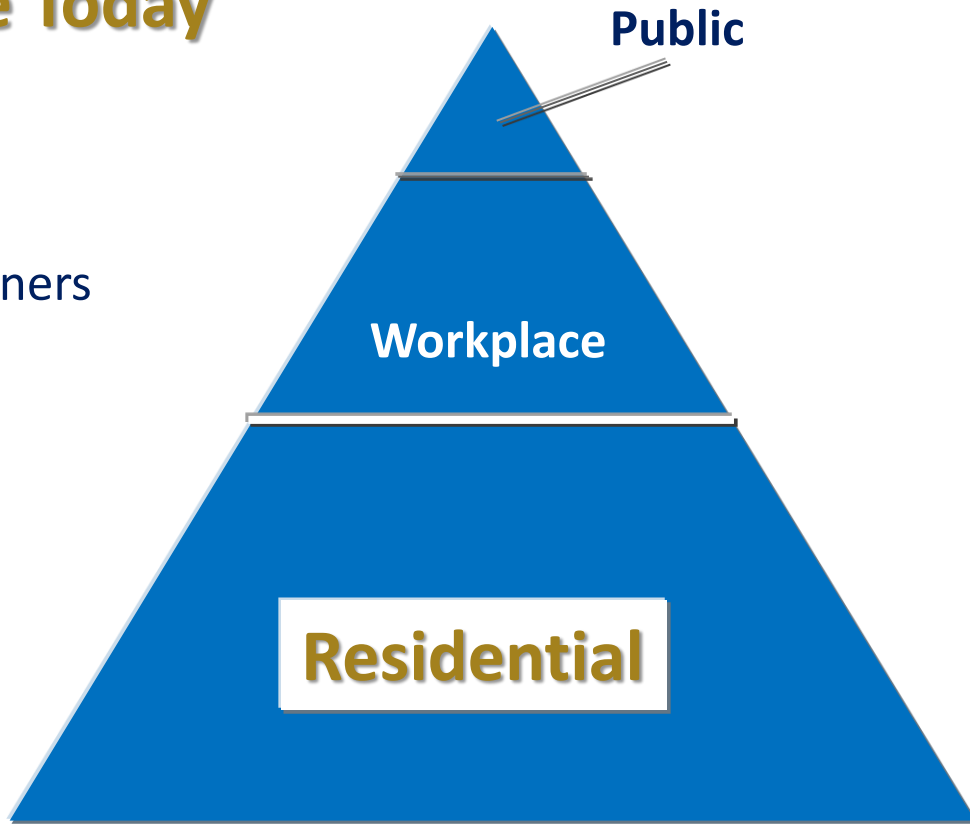
Image May be a Sound Commercial Reason for Electric Drive.

- If the best market has many stops, this can mean a lot of exposure per $ spent.
- Cleanliness at the tailpipe is a fact, is good.
- Quiet operation a plus (but sound is now added).
- Idle reduction laws are not a problem for EVs.
- Operation at more times and locations may be accepted by customers, authorities.

Charge Supply Equipment

EPRI View: Charging Infrastructure Must Not Become a Barrier to Adoption

- **Build Today's Infrastructure Today**
- Infrastructure is expensive
- Focus on Residential
  - Seamless installations for homeowners
  - Permits, electricians, inspections
  - Rates and customer programs
- Workplace
  - Includes fleet and retail
- Public Charging – as needed
  - Retail, private, public spaces
  - Know what drivers need – location, open access, billing
  - **What are the viable business models?**



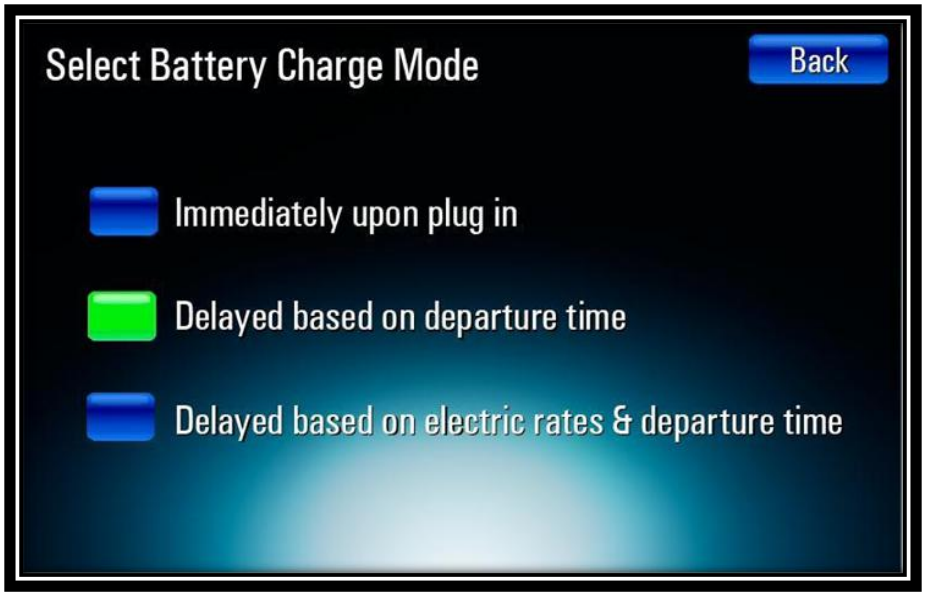
Source: A. Maitra. Plug-in Vehicle Drive Impacts to the Grid. Transportation Research Board 2010 Environment and Energy Conference, June 7-9, Raleigh NC

Clever Use of Existing Utility Infrastructure Should be Goal 1.

- Avoid charging on or near the peaks –
  - **Avoid late afternoon or early evening on hot summer days**
  - This has been estimated to cause needs for new capacity
- Charging PHEVs and EREVs overnight (residential with 1.4 kW to 3.3 kW chargers) is good
  - Analyses of many cases predicts more natural gas use and less coal use than the utility average. Plug-ins can consistently be cleaner than gasoline.
  - The future should be even better: national natural gas resources have increased, gas prices have come down and more and more gas-electric generation is being planned.
- Charge ending by morning departure is a good approach
  - Economic for utilities, since no new capacity will be needed
  - Environmentally good because natural gas use will be high
  - Battery life will probably be better

Light Duty Plug-in Charging

Automakers are Providing Features Making Early Evening Summer Charge-on-Arrival Only One Option



Other Options:

- Fill by departure
- Pre-cooling/heating
- During off peak rate

Costly control strategies may not be necessary if consumers voluntarily behave in a manner that minimizes grid impact.

Standards Take Time, are Done for AC up to 19.2 kW, but Higher kW is in Contention.

- Most PHEV and EREV *on-board* chargers go to 3.3 kW, do not have DC charge acceptance capability for available *off-board* 50 kW DC level 2 chargers.
- AC equipment < 19.2 kW is standardized & certified. (AC level 1 is 1.4-1.9 kW; Level 2 is 3.3 to 19.2 kW).
- Level 2 supply equipment interoperability is not now assured, even with present standardized AC chargers. SAE is working on it, for Model Year 2014.
- Today's Leaf EV has a Japan-derived "2 port" *option* for slow and quick (i.e. 50 kW) charging. SAE and IEC (Europe) are promoting a one port std.

Households May Have to Install a New Circuit to Have a Plug Close to the Vehicle

- AC Level 1 – 120 v outlet
  - In most garages
  - Does outlet have the capacity?
  - Prefer dedicated outlet

Level 1 at Wall

Level 1 Portable Charge Equipment

- AC Level 2 – 240 v special connector
  - Defined by SAE J1772
  - Cord connected to a charging dock (EVSE)

Level 1 or 2 at the Vehicle

Level 2 Wall Mounted Charge Dock

Be Sure "Authorities Having Jurisdiction (AHJs)" Install & Inspect AC Level 2 Equipment Installations

- **Certified, trained electrical inspectors are the best protection**
  - ✓ Follow code requirements; state and nationally

- **Inspection process**
  - ✓ Location
  - ✓ Installation/wiring completed properly
  - ✓ Equipment listing marks
  - ✓ Diagrams and calculations
  - ✓ Safety
  - ✓ Release job

See: ***EVSE Residential Charging Installation Video*** at http://cleancities.tv
http://www.cleancities.tv/FeaturedContent/Training/EVSEResidentialChargingInstallation.aspx

The more powerful the charger and the older your local transformer, the more important to assure AHJs communicate with your utility

Medium Duty Commercial Truck Charging

AC Level 2 Top kW May be Adequate for Night Charge of Medium Duty EVs

Truck brand	Reported pack kWh	Hours/charge @ 19.2 kW*
Electric Vehicles International	99	5.2+
Azure Dynamics Transit Connect	28	1.5+
Freightliner Custom Chassis E-Cell	55	2.9+
Navistar eStar	80	4.2+

***The last few kWh of charging are usually managed by battery controls, at a lower kW level**

Source: Long, M. *Looking at Electric Trucks*. Light and Medium Truck, May 2011 pp. 12-15.

Fleet EVs Must be Driven Slowly, Often, & Many Hours. Keep Charge Equipment $ Low.

- *Any* drivetrain that increases vehicle purchase price and lowers fuel costs becomes more cost effective if driven a lot (days & hrs./day).
- An HEV, PHEV, or EREV can increase hours while traveling further and faster — an EV cannot.
- If an EV has high hours/day, it must have low average speed (slow stop and go urban delivery) to avoid labor time costs of work shift re-charge.
- Some electric circuit and vehicle supply equipment cost problems are:
  - long distance from existing electrical service to parking spot
  - much pavement/sidewalk/walls to tear up & redo
  - putting your building at a higher kW level & wiring upgrades needed
- If starting new construction, planning ahead before construction can *sharply* reduce charge equipment installation cost.

Commercial Rate "Fuel Charges" Can be Very Cheap. Watch the Demand Charge!

- Can you fold the fleet into your existing rate bracket and avoid demand charges?
- Are you going to limit yourself to one charge per day and do it at night?
  - If not, when, where and how?
  - Demand charges are for a reason, don't increase peak kW
- If there are going to be fast chargers in your region, can your vehicles use them?
- Is the next generation of electric vehicles going to work with your chargers?

Coming Plug-in Cars: What and When?

Personal Use Plug-in Vehicle Options Fall into Three Major Categories

Plug-in Hybrids (PHEV)
(engine on ~ 60 mph, or hard acceleration)

PHEVs are similar to hybrid electric vehicles on the market today, but have a larger battery that is charged both by the vehicle's gasoline engine and from plugging into one of your electrical outlets or perhaps a charging station

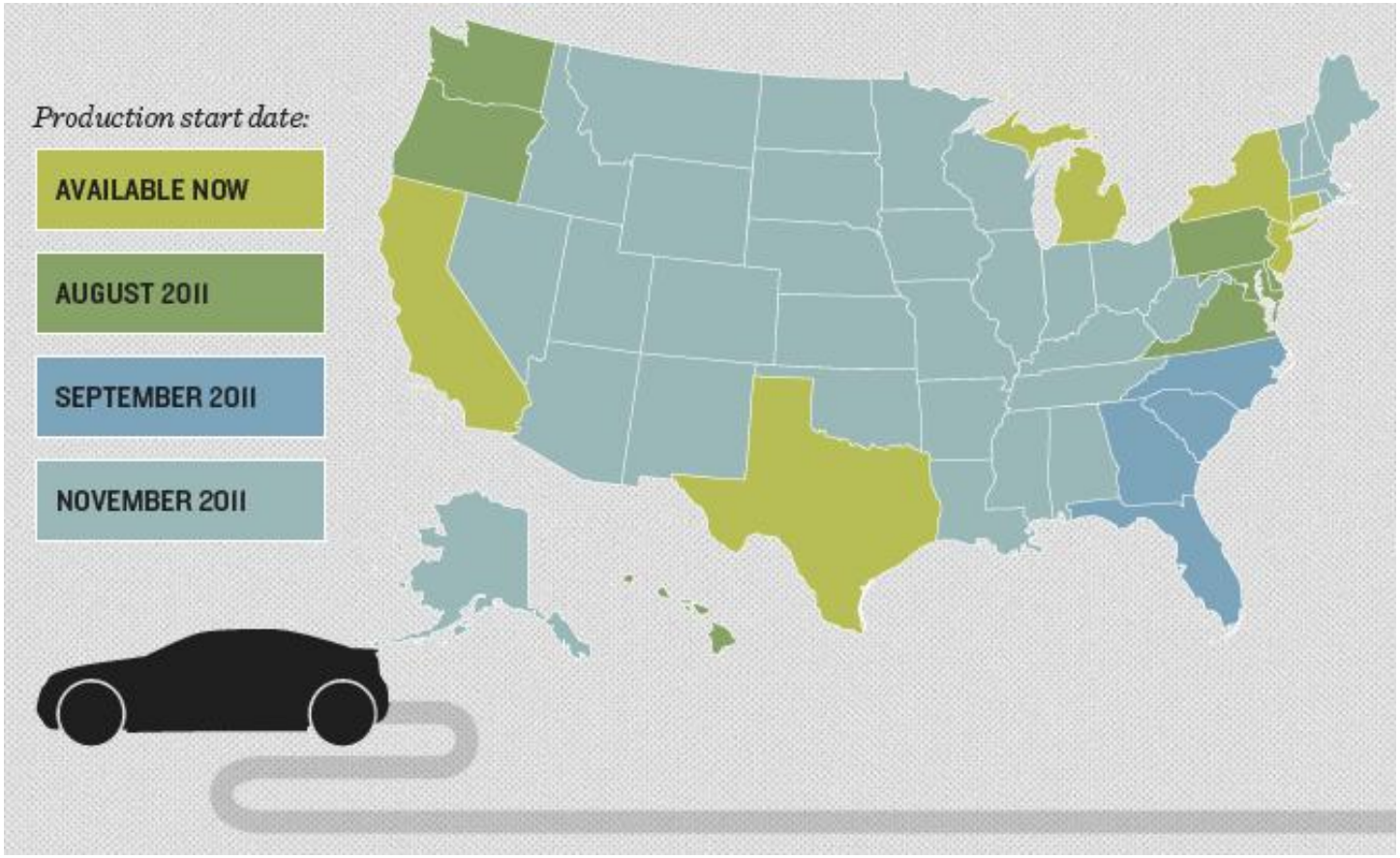
Extended Range Electric Vehicles (EREV)
(all electric all the time, until battery is empty)

An **EREV** is a short range EV with an engine to allow farther driving of the vehicle when the batteries become low. It operates as an EV on stored electricity initially and then uses a gasoline engine to operate as a hybrid.

Battery Electric Vehicles (BEV)
(all electric all the time)

A **BEV,** otherwise known as a pure electric vehicle, is powered by an electric motor rather than a gasoline engine.

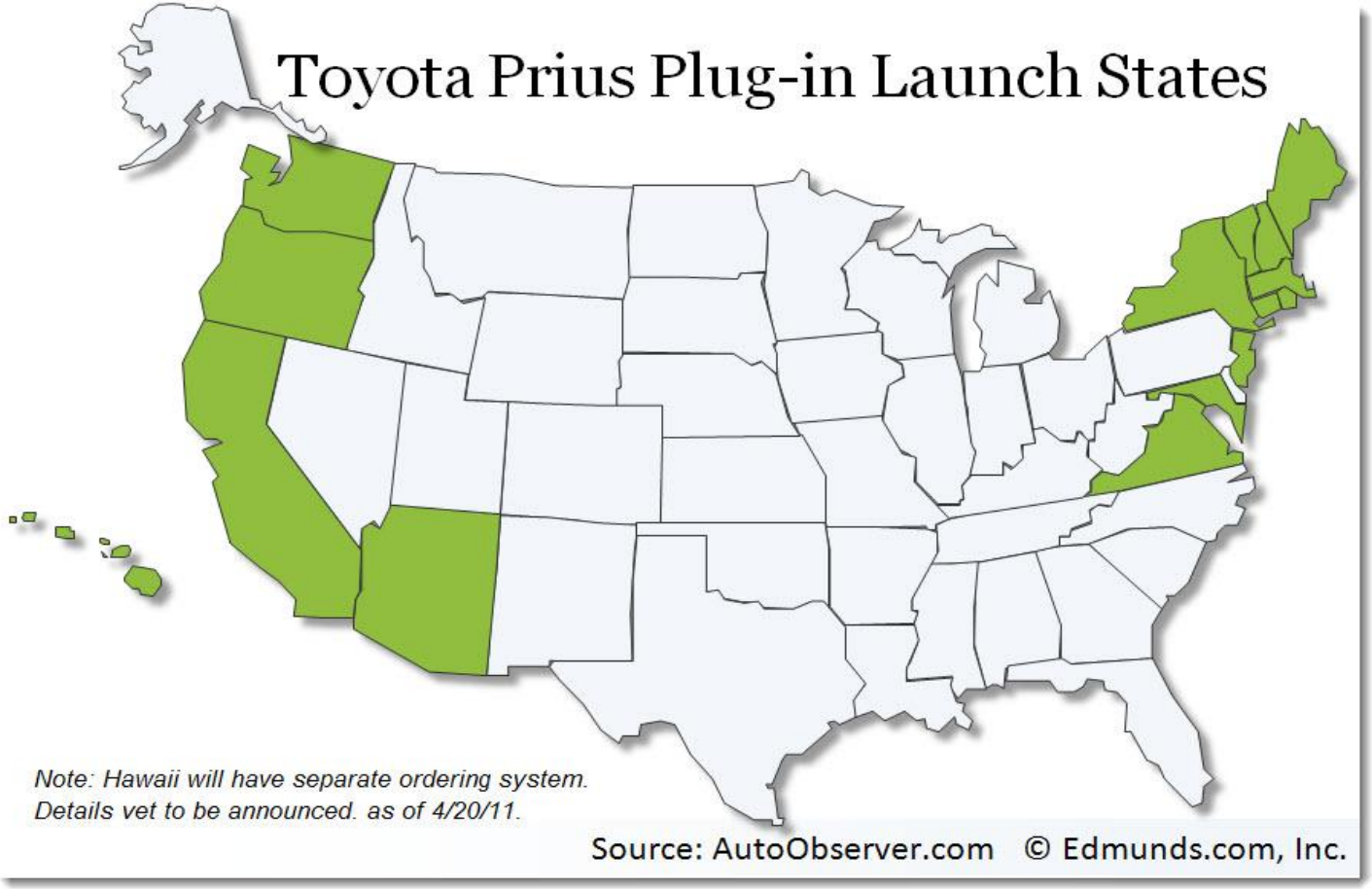
EREVs & EVs: The Volt EREV is Here in November, the Leaf and MiEV EVs in 2012/13



The **Leaf** will be available to consumers in Alabama, Florida, Georgia, North Carolina, Maryland, South Carolina and Virginia in the fall, with nationwide ordering kicking off in 2012, said Nissan. (**Nissan Leaf Set To Go Mainstream: 2011 N. Y. Auto Show.** http://www.insideline.com/nissan/leaf/nissan-leaf-set-to-go-mainstream-2011-new-york-auto-show.html**.** 4/20/11**)**

"MiEV … nationwide rollout expected by December 2012". http://www.engadget.com/2011/04/23/mitsubishi-i-miev-priced-to-move-rolls-out-slowly-across-us/

PHEVs: Plug-in Prius not Available in Kentucky in 2012. Ford C-Max Energi Appears TBD (2012?)



Ford will launch the **C-MAX Energi** plug-in hybrid electric vehicle and C-MAX Hybrid in 2012 in North America. http://www.conceptcarz.com/z19386/Ford-C-Max-Energi.aspx.

Thank You!

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Appendix: SAE J1772™ Task Force Charge System Names vs. Readiness and Power (kW)

Type AC	Power Level
AC Level 1 120 VAC	12, 16 amps 1.44, 1.92 kW
AC Level 2 208 - 240 VAC	≤ 80 amps 3.3 to 19.2 kW
▲AC Level 3 TBD Single or three phase?	

AC Level 1 & 2 Chargers are small and on-board the vehicle

Type DC	Power Level
None at this voltage	None at this power
▲DC Level 1 200 – 450 VDC	≤ 80 amps ≤ 19.2 kW
▲DC Level 2 200 - 450 VDC	≤ 200 amps ≤ 80 kW
▲DC Level 3 TBD 200 – 600 VDC?	≤ 400 amps? ≤ 240 kW?

DC Chargers are large and off-board the vehicle

Only AC Level 1 and 2 are finalized by SAE, but the Leaf has an optional Japanese 50 kW DC quick charge ***port*** (yellow box, "DC-JARI ChAdEMO", generally 50 kW).

▲ Not finalized by SAE