REAL SOLUTIONS FOR CLIMATE CHANGE

Electric Vehicles - What, When, Why, and How

March 17, 2011

Presented by:

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Introduction to Plug-in Hybrid and Electric Vehicles:

MARCH 17, 2011

Presented by:

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Moving to Electric Drive

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Bigger Batteries

Bigger Engines

Internal Combustion Engines (ICEs)

Hybrid Electric Vehicles (HEVs)

Plug in Hybrid Vehicles (PHEVs)

Electric Vehicles (EVs)

Toyota Prius HEV / Honda Civic HEV

PHEV 5 → 60 Miles Blended → AER

Prius Plus 20 PHEV GM Volt 40 PHEV

Tesla EV

Gasoline/Diesel Dependent

Electric Grid Dependent
# Reducing Your Transportation Footprint:

Based on the following criteria: miles driven per year = 10,000, 1 gallon of gas = 19.37 lbs. CO₂, standard vehicle 25 mpg and uses 379 gallons of gas/yr, hybrid vehicle 45 mpg and uses 211 gallons of gas/yr, plug-in hybrid 70 mpg and uses 135 gallons of gas/yr. Battery Electric Vehicle pack size 24 kWh, BEV consumption per year = 26.40 kWh, PG&E electrical grid 0.52 lbs. CO₂ per kWh of electricity.

### Eliminate 10 Miles of Driving per Week:
- 403 lbs. of Carbon Dioxide Eliminated
  - Ride a bike
  - Walk
  - Work From Home
  - Ride Public Transportation
  - Carpool
- 52 weeks per year = 520 miles
- 1 gallon of gas = about 20 lbs. of CO₂
- That's about 21 gallons of gas saved per year!
- 21 gallons of gasoline creates about 403 lbs. of CO₂
- With a little effort and planning, anyone can do this.
- Possible to reduce CO₂ footprint further, by driving less!

### Purchase a Hybrid Vehicle:

<table>
<thead>
<tr>
<th>Model</th>
<th>MPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota Prius</td>
<td>48</td>
</tr>
<tr>
<td>Honda Civic</td>
<td>43</td>
</tr>
</tbody>
</table>
| 211 Gallons of gas used per year
- About 169 gallons less per year than standard 25 mpg vehicle!
- At about 20 lbs. CO₂ per gallon of gas, that's 3265 lbs. of CO₂ eliminated per year!

### Purchase a Plug-in Hybrid Vehicle:

<table>
<thead>
<tr>
<th>Model</th>
<th>2011 Chevy Volt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011 Toyota Plug-in Prius</td>
</tr>
<tr>
<td></td>
<td>2011 Fisker Karma</td>
</tr>
</tbody>
</table>
| 4523 lbs. of Carbon Dioxide Eliminated
- About 244 gallons less per year than a standard 25 mpg vehicle!
- At about 20 lbs. CO₂ per gallon of gas, that's 4523 lbs. of CO₂ eliminated per year!

### Purchase an All Electric Vehicle:

<table>
<thead>
<tr>
<th>Model</th>
<th>2010 Nissan LEAF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011 BMW Active E</td>
</tr>
<tr>
<td></td>
<td>2011 Ford Focus</td>
</tr>
</tbody>
</table>
| 6035 lbs. of Carbon Dioxide Eliminated
- Saves 379 gallons of gas used per year in a standard 25 mpg vehicle as electric vehicles use no gas!
- Only emissions are "upstream" and created during electricity generation
- A large portion of PG&E's system generation is hydro, nuclear, wind, and solar
- On the PG&E system, 1 kilowatt hour accounts for 0.524 lbs of CO₂
- BEV with 24 kWh battery pack is estimated to use 26.40 kWh/yr.
Fuel and CO2 Savings

- Reduce driving
- Drive a Hybrid
- Drive a PHEV
- Go all-electric

<table>
<thead>
<tr>
<th>Option</th>
<th>Fuel savings (gallons)</th>
<th>Carbon Dioxide reductions (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce driving</td>
<td>-21</td>
<td>-3265</td>
</tr>
<tr>
<td>Drive a Hybrid</td>
<td>-403</td>
<td>-5958</td>
</tr>
<tr>
<td>Drive a PHEV</td>
<td>-169</td>
<td>-4523</td>
</tr>
<tr>
<td>Go all-electric</td>
<td>-244</td>
<td>-4000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-6000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-7000</td>
</tr>
</tbody>
</table>
**CO₂ benefits depend on:**

- **Battery size & range:** PHEV 10 to PHEV 40+
- **Lifestyle:** frequency of travel over “electric range”
- **Charging opportunities:** Home, Work, Costco, Starbucks
- **Price of gasoline & electricity**
- **Instrumentation of vehicle**
- **Speed and Terrain**
PHEV Operating Costs

- Assumptions: mid-size car, baseline PG&E rates, 3$/gal and conventional vehicle fuel economy of 30 mpg

- Electric: 11.09 cents/kWh * .25 kWh/mi = 2.77 ¢/mile

- Gasoline only: (3.00$/Gal)/(30 mi/gal) = .10$/mi = 10 ¢/mile

- Conventional Hybrid: (3.00$/gal)/(48 mi/gal) = .0625 $/mi = 6.25 ¢/mile

- Plug-in Hybrid: (Not so easy to calculate, depends on how long you drive, if you charge, etc.) = 3-6 ¢/mile
Median Generation and Demand for the Month of August (CA)

- CA can easily demand 85% of maximum generating capacity on-peak.
- Below 50% demand off-peak.
- Last 25% of generating capacity is used less than 10% of the time; last 5% of generating capacity used less than 50 hrs/year.
- Analysis shows the CA grid can charge 1 Million PHEVs off-peak, accounting for less than 1% of total electricity demand.
- Wind and solar are complementary renewable energy sources.

Source: Christopher Yang, UC Davis
Charging Options

• **120 V**
  - Slow, but works with a standard outlet, may find more charging opportunities, may be up to 24 hrs to fully recharge

• **240V**
  - Home recharging, requires a charging unit to be installed, typical 4-6 hour recharging time
  - Works for public charging at places where you WANT to be for a few hours

• **Fast-charging**
  - 20 minutes for about 80 miles of range, may allow for extended driving distances
  - Requires serious and expensive charging unit and installation
New ARRA Tax Credit

- **Plug-In Electric Drive Vehicle Credit**
  - Vehicles with 4 wheels and GVWR<14,000 lbs
  - Purchased after Dec. 31, 2009
  - Battery with at least 4 kWh that can be recharged from an “external source of electricity”
  - Minimum credit of $2,500, up to $7,500 depending on the size of the battery ($417/kWh after 4kWh)
  - Credit phases out after the manufacturer has sold at least 200,000 vehicles

- FS-2009-10, April 2009, Section 1141
Issues Surrounding Fast Chargers

Legend
Distance From Davis (mi)

Fast Chargers
KWHr per Month
- 9 - 14
- 15 - 23
- 24 - 42
- 43 - 80
- 81 - 134
- All Monthly Travel (10 households)
10 Households, ~1 Month of Data
Mini E Study Provides Insight

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Where did they “want to go but couldn’t due to range issues?”
Route Density

Legend
“Places I want to go but can’t” Relative Route Density
Number of Responses
- 1
- 2 - 3
- 4 - 7
- 8 - 19
- 20 - 29
- 30 - 99
- Home Locations
Destination Breakdown

Desired Destination Categories and Range Distribution From Maps 2 & 3 (n=126)
Three charger scenario
Section 5: Your Household

The information in this section will be used only for descriptive purposes. We need to know how well our respondents match the descriptions of households who buy new cars in the United States.

5) Where do you live?
This information is used only for the survey purposes.
Note: You can move the location marker.

Address or intersection: 3rd and u
City: davis  State: CA  Zip Code: 95616

Formatted Address: 3rd St & University Ave, Davis, CA 95616
If the point on the map is not the correct location please move the red marker or
Retry with a new address
If the marker is the right location, click Next

http://gis.its.ucdavis.edu
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Electric Vehicles and the Power Grid

March 17, 2011

Presented by:

Esrick O. McCartha
Client Manager
PJM Interconnection, LLC
PJM’s Responsibilities

- Ensures the reliability of the high-voltage electric power system
- Coordinates and directs the operation of the region’s transmission grid;
- Administers a competitive wholesale electricity market;
- Plans regional transmission expansion improvements to maintain grid reliability and relieve congestion.
PJM’s Responsibilities

Operators of Energy Markets…

Air Traffic Controllers for the Transmission Grid…

SIMULTANEOUSLY!

RELIABLY!
PJM as Part of the Eastern Interconnection

KEY STATISTICS

- PJM member companies: 650+
- Millions of people served: 51
- Peak load in megawatts: 144,644
- MWs of generating capacity: 164,905
- Miles of transmission lines: 56,250
- GWh of annual energy: 729,000
- Generation sources: 1,310
- Square miles of territory: 164,260
- Area served: 13 states + DC
- Internal/external tie lines: 250

26% of generation in Eastern Interconnection
23% of load in Eastern Interconnection
19% of transmission assets in Eastern Interconnection
19% of U.S. GDP produced in PJM
The Smart Grid is realized by merging data from these areas of automation to achieve a total end-to-end system view by integrating information technology and operational technology.

**ISO/RTO**

- SCADA and Phasor Measurements
- Substation Automation
- Transmission & Sub-transmission
- Distribution
- Generation
- Energy Storage
- Smart Metering, Demand Response, PHEV, Energy Conservation and Distributed Resources
- Customer

**Two-Way Communication and Control**

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Smarter Grid Network – Smart Home

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- Smart Appliance
- Energy Management
- Smart Charger (PHEV) Storage

- Ancillary Services Signals
- Price Signals
- Generation Mix

- Reliability Control
- Load Curtailment
Integrate SMART Grid with PHEVs

- Enable greater penetration of PHEVs through coordination with state SMART Grid and retail tariff innovation initiatives
- Develop infrastructure to support non-traditional demand based regulation resources
- Develop operational tools and forecasting techniques to enable PHEV deployment

- Develop Vehicle to grid / Plug-in hybrid electric vehicles (PHEVs) protocol
- Participate in Mid-Atlantic Grid Interactive Cars Consortium (MAGICC) – electric companies, research institutes, and vehicle manufacturers
- Test storage batteries in regulation markets
Vehicle Economic Charging

Assumptions
- 1,000,000 PEV Vehicles by 2015
- ~18% of U.S. Population is within the PJM territory
- ~180,000 PEV Vehicles in the PJM Territory
- ~33** Miles traveled per vehicle per day
- ~18% of U.S. Population is within the PJM territory
- ~180,000 PEV Vehicles in the PJM Territory
- ~33** Miles traveled per vehicle per day
- ~Average vehicle fuel usage: 22** mpg
- ~No tax compensation

Daily cost per PEV Vehicle
- Gasoline: 33 miles/day * $3.00 /gal // 22 miles/gal = $4.50
- Electric: 33 miles/day * $.07 /kWh // 4 miles/kWh = $0.60

Annual cost/savings
Cost:
- Gasoline: 365 days * $4.50 /day = $1650
- Electric: 365 days * $0.60 /day = $220

Savings:
- ~$1400 annually per vehicle
- 180,000 vehicles (within PJM) = ~$250,000,000 annual

** U.S. Bureau of Transportation Statistics
Wind Generation in PJM - Operational and Proposed

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45,192 MW

* In planning queue - August 2009
PJM Load and Wind Resources – August 26, 2009

PJM Load and Wind Contribution
August 26, 2009

- PJM Load, MW
- PJM Total Wind, MW

Chicago LMP
August 26, 2009

Locational marginal Price - $/MWh
Vehicle Charging Impact on PJM

Charging Energy
180,000 PEV Vehicles * 33 miles // 4 miles/ kWh = ~ 1500 MWh

~ 500 additional MW over 3 valley hours
Fast Regulation: Speed Matters…

A fossil power plant following a regulation command signal

Energy Storage (batteries / flywheels) accurately following a regulation command signal
Grid Benefits – Regulation vs. Economic Dispatch

- Load in GW
- Time on the Road
- Regulation
- Battery Response
- Economic Charging
- 50mSec Charge/Discharge
- Hour of Day
- Dependent on State of Charge
- Capacity for 25+ million PHEVs
Vehicles w/ Vehicle-2-Grid Participating in the Regulation Market

Vehicles
- ~18% of U. S. Population is within the PJM territory
- 180,000 PEV Vehicles in the PJM Territory

V2G Equipped PEVs within PJM
- Assume 10% of Vehicles have V2G capability
- Bi-Directional Power (with inverter) – 15 kW
- 18,000 vehicles * 15 kW = 270 Mw

Availability for Participating in Regulation
- Plugged In 12 hours each day (6PM – 6AM) > 365 days * 12 hours = 4380 hours/year

Payment for participation in the PJM Regulation Market
- PJM average historic price paid for regulation = $35/MWh
- PJM Regulation price during valley load periods = $28/MWh
- Per Vehicle: 4380 hrs * $28 * .015 MW = $1800 annually
- PJM Overall: 4380 hrs * 270 MW * $28 = ~$33,000,000 annually
Will Work for Fuel

480,000 Vehicles in United States
Average ~50 miles per day
Parked for 3 months
Great public visibility
MAGICC – PJM’s PHEV Demonstration Project

• Smart Meter allows car to roam
• Mid-Atlantic Grid Interactive Car Consortium (MAGICC)
• Over one year experience
AES Grid-Scale Energy Storage System

 Operational Details

- Altairnano, Inc – Lithium Ion nano titanate battery
- Power: 1 MW for 15 minutes
- Usable Charge Range: 5% - 99%
- Energy: 300 kWh
- Efficiency: 90% round trip
"Cash Back" for Storage

1 MW

~ $850/day

1.018 MW

~ $10/day (20 Hrs.)

Smart Grid Network

- Frequency Regulation Signal

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PHEVs: The Momentum Builds

**Battery Electric Vehicles**
- 2010 Coda Automotive Sedan
- 2010 Mitsubishi iMiEV BEV
- 2010 Nissan LEAF
- 2010 Ford Battery Electric Van
- 2010 Tesla Roadster Sport EV
- 2011 Peugeot Urban EV*
- 2011 Renault Kangoo Z.E.
- 2011 Renault Fluence Z.E.
- 2011 Tesla Model S
- 2011 BYD e6 Electric Vehicle
- 2011 Ford Battery Electric Small Car
- 2011 Opel Ampera Extended Range BEV*
- 2012 Fiat 500 minicar

**Extended Range Electric Vehicles**
- 2010 Chevy Volt Extended Range

**Plug-in Hybrid Vehicles**
- Fisker Karma S Plug-in Hybrid
- 2010 Toyota Plug-in Hybrid
- 2011 BYD F3DM Plug-in Hybrid
- 2012 Bright Automotive IDEA Plug-in Hybrid
- 2012 Ford Plug-in Hybrid
- 2012 Volvo Plug-in Hybrid
West Philly: EVX GT
Plug-In Parallel Hybrid Electric Vehicle

www.pjm.com
Smart@Car Current Research Activities

- Modeling of PHEVs and interactions with the grid
- PHEV Energy Management
- PHEV-Grid Connectivity Issues
- PHEV Fleet Studies

www.pjm.com
Smart@Car-a connection to the grid
1. Reduce Oil Imports/Energy Independence
2. Reduced Cost of Fuel and Cash Back
3. Reinvent Auto Industry
4. Recharge Off Peak/Higher Use of Power Industry Assets
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The West Coast Green Highway:
I-5 Electric Highway Public/Private Partnership Project

March 17, 2011

Presented by:

Jeff Doyle
Director of Public/Private Partnerships
Washington State Department of Transportation
U.S. oil dependence weakens our national security, threatens our economy, and degrades the environment.

**National Security Costs of Oil Dependence:**
- Securing global supply lines: $67.5 - $83 billion per year

**Economic Costs of Oil Dependence:**
- Every recession over past 35 years preceded by – or concurrent with – an oil price spike

**US Oil Dependence: Economic Costs**

[Histogram showing household gasoline expenditures over years]
Environmental Costs of U.S. Oil Dependence:

- The transportation sector is the single largest *end-use emitter* of carbon dioxide in the U.S (34 percent of total CO2 emissions).

- To reach a 450 ppm Co2 stabilization target, by 2030 more than 60 percent of new vehicle sales must be electric drive.
GHG emissions from Washington State’s transportation sector (47%) are nearly double the national figures.
2008 WSDOT Alternative Fuels Corridor Economic Feasibility Study:

“The primary challenge to Alternative Fuels commercialization is how to build a market – simultaneously – for new vehicle technologies, new fuels, and new infrastructure to support them.”

http://www.wsdot.wa.gov/Funding/Partners/AltFuelsCorridor.htm
## Comparative Factors for Alternative Fueling Stations

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Land &amp; Building</th>
<th>Fueling Equipment</th>
<th>Supply Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>$1,348,500</td>
<td>$571,000</td>
<td>Established</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>(Co-located?)</td>
<td>$127,000*</td>
<td>Limitations</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>(Co-located?)</td>
<td>$318,000</td>
<td>Not Established</td>
</tr>
<tr>
<td>Electricity</td>
<td>Kiosk</td>
<td>$50,000 - $90,000**</td>
<td>Grid</td>
</tr>
</tbody>
</table>

* Number of pumps scaled for smaller initial demand  
** Upper range includes utility connections and necessary upgrades
Why Electric?

Fuel Source: Electric Power Grid

Advantages:

- Diverse and domestic
- Prices are stable
- Substantial spare capacity
- Network infrastructure already in place
- Electric miles cheaper than gas
- Electric miles are cleaner than gas
- 65 percent of present U.S. light-duty vehicles could be powered by existing off-peak generating capacity
Electric Vehicles: Battery Electric (BEV) vs. Plug-in Hybrid (PHEV)

Example: Nissan LEAF
- All Electric Range: 60 - 200 Miles, depending on battery size
- Level 1 (120 v), Level 2 (240 v) and optional Quick-Charging (480v)
- Target markets:
  - Urban Commuters
  - Second Car in Every Home
  - Eventually: all-purpose

Example: Chevy Volt
- Battery Electric plus ICE range extender
- 10-40 mi all-electric, 200-300 mi gas
- Level 1 (120v) and Level 2 (240v) Charging
- Target Market: all automotive applications
## Why Electric?

### Nissan LEAF Range and Vehicle Efficiency

<table>
<thead>
<tr>
<th>Speed and Driving Conditions</th>
<th>Outside Temp (F)</th>
<th>Accessories</th>
<th>Estimated Range (mi)</th>
<th>Vehicle Efficiency (mi/kWh)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruising 38 mph</td>
<td>68°</td>
<td>None</td>
<td>138</td>
<td>5.75</td>
</tr>
<tr>
<td>Fairly steady 24 mph</td>
<td>77°</td>
<td>None</td>
<td>105</td>
<td>4.38</td>
</tr>
<tr>
<td>City traffic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steady 55 mph Highway</td>
<td>95°</td>
<td>A/C on</td>
<td>70</td>
<td>2.91</td>
</tr>
<tr>
<td>Crawling 15 mph Stop-and-go</td>
<td>14°</td>
<td>Heater on</td>
<td>62</td>
<td>2.60</td>
</tr>
<tr>
<td>Average 6 mph Heavy stop-and-go</td>
<td>86°</td>
<td>A/C on</td>
<td>47</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Nissan LEAF has a 24 kWh battery

Why Electric?

EV’s are not fully utilized when “range anxiety” exists

Source: Tokyo Electric Power Company (TEPCO)
Why Electric?

Strategically-located Quick Charge stations alleviate range anxiety

Source: Tokyo Electric Power Company (TEPCO)
Why Electric?

Strategically-located Fast Charge stations alleviate range anxiety

Drivers returned EV’s with > 50% SOC

Drivers returned EV’s with < 50% SOC

Source: Tokyo Electric Power Company (TEPCO)
Project Purpose: Commercialization of Electric Vehicles

- Develop safety net of EV Quick-Charging stations throughout Interstate 5 Corridor – WSDOT’s niche is outside Seattle-metro area

- Form public/private partnerships: with retailers to serve as station hosts, and with DBFOM consortium to develop, install and operate chargers

- Coordinate EV infrastructure development with other EV infrastructure planned for Seattle, Vancouver, BC, State of Oregon (ODOT), and eventually, California (missing link)

- WSDOT seed funding: $1.32m US Department of Energy grant for petroleum reduction projects (through Washington State Commerce Dept.)
Public/Private Partnerships for EV Infrastructure

Two-Stage Deployment: Essential Charging and Corridor Completion

- **Funding:** $1m federal grant for capital seed funding. Seeking DBFOM partner for maximum leverage (fixed price, variable scope).

- **Target completion date:** October 31, 2011.

- **Focus:** Ease of use for consumers. Turn-key for government sponsors.

- **Minimum Number of DC Quick Charge Stations:** 9 stations (7 on I-5, 2 along SR-2)
Supportive State Actions

Issues to Consider (from WSDOT’s perspective):

- Capital efficiency of PPP (leverage) vs. strong government ownership role
- What happens after Year 3 (turn-back)?
- Long-term sustainable business model?

Opportunities and Resources for State DOTs and Municipalities

- Transportation Pooled Fund Study Opportunity: “Strategies and Best Practices for State Departments of Transportation to Support Commercialization of Electric Vehicles (EV) and Infrastructure” Solicitation #128 [http://www.pooledfund.org/projectdetails.asp?id=1289&status=1](http://www.pooledfund.org/projectdetails.asp?id=1289&status=1)
- West Coast Green Highway ([www.westcoastgreenhighway.com](http://www.westcoastgreenhighway.com))
- The EVProject ([www.TheEVProject.com](http://www.TheEVProject.com))
I-5 Electric Highway Public/Private Partnership Project

For more information, contact:
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www.westcoastgreenhighway.com
For copies of these slides and webinar recording, go to AASHTO’s website: 
http://environment.transportation.org/center/products_programs/climate_change_webinars.aspx

These materials will also be available on AASHTO’s climate change website, where you can also find more information on climate change: 
http://climatechange.transportation.org/webinars/

Thank you!