Electric Mobility
PHEV Workshop
Objective: Canada Energy Sustainability

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Goals for energy sustainability

- Enhanced life style with more comfort, productivity and flexibility while using much less oil energy while greatly improving efficiency.
- Lower cost energy for both transportation and stationary homes, shops and factories.
- Integration of renewable energy sources such as Water, Wind, Solar and Bio mass in the form of Ethanol and Biodiesel with conventional sources for gradual transition.

Transition from petroleum, coal, natural gas to completely Renewable energy resources without a disruption of lifestyle. Beginning with NOW available infrastructure and technology.
What is a PHEV??

- The Plug-In HEV is like a Toyota Prius except it has a **smaller** engine and a **larger electric motor and battery pack** and a **plug** to the wall to charge the batteries!! ---No weight increase due to batteries!!

- This combination allows the vehicle to have **better** fuel economy, **higher** performance, and **All Electric Range (AER)** up to 60 miles with a **much simpler** powertrain and no increase in weight. AER is done with batteries from 100% SOC to 20% SOC then the engine maintains at 20% SOC. Then when you stop driving you plug-in and fill the batteries from the wall. If you don’t plug-in you simply use more liquid fuel. No loss in performance!!
What Energy infrastructure are we talking about?

- The current energy infrastructure that we have set up for our society + Computer controls
- 120v Electric GFI plugs in the home and on the streets with energy management computer chip.
- Gasoline and Diesel stations
- Home garages with 120v GFI plugs and Utility control Chips
- Batteries in the PHEV cars—distributed in society
- Note PHEV cars all have energy management systems already on a CAN bus.

The Average person drives his car 3 hours/day, meaning it is parked 21 hours/day ~~~ So, there is plenty of time to charge, discharge and recharge the batteries of a PHEV with 120v plugs.
Shade and Charging Shelters

3.5 kW EV Charging Station

10 kW EV Charging Station

12 kW School Lunch Shelter

30 kW Parking Shade Structure
Cost effectiveness of Solar systems used to charge PHEV Batteries

• A 10 kw solar system charging PHEV’s, is good for 30 miles of driving for each hour of sun for a mid size car. (Cost-$8/watt-$3/watt rebate=$5/watt. New syst. Are cheaper)

• This is equivalent to producing a gallon of refined gasoline an hour ~ $3.00/hour.

• At $3.00/hour of operation and about 300 days a year at 8 hours of sun, the yearly money made by the 10kw array is about $7200.

• Payback should be about 6 years at this rate.

Solar is not so competitive with electricity at 4 cents/kwhr. Since it means that the revenue generated above would be only $0.40/hr Taking 48 years to pay back!! – A new industry is born!!
Small Solar & Wind versus Large Solar & Wind

- Small solar is cost effective for **personal energy independence**
- Using PHEV energy storage will be able to integrate the Home and Office energy with Transportation.
- Provide emergency power
- Provide for daily energy dependent activities including transportation, communications during future energy shortages
- Ability to feed energy back to the grid at the **appropriate** time from **storage in PHEV!!**
60 mile AER PI-HEV vehicles with CVT’s constructed at UCDavis to show technology is here today!! Supply Chain for parts Developed!!

- **EV1-PHEV**
  - 80mi AER, 80mpg

- **’94 Mercury Sable**
  - 60 mi AER, 58 mpg
  - Automatic mechanical CVT

- **2000 Suburban**
  - 60 mi AER, 28 mpg
  - New automatic CVT
  - Being installed
New PHEV that will run on Sunshine and a little Ethanol
4000 lb Chev. Equinox 210hp electric 90hp ethanol
Lithium batteries, 120v charging 80% elect. 20% ethanol
Greenhouse Gas Emissions for all light duty cars trucks

Increasing Hybridization →
### Annual Gasoline Consumption for 12,000 miles of driving-all L/D vehicles

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Conventional</th>
<th>HEV0</th>
<th>HEV20</th>
<th>HEV60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact Sedan</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Midsize Sedan</td>
<td></td>
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<tr>
<td>Midsize SUV</td>
<td></td>
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<tr>
<td>Fullsize SUV</td>
<td></td>
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</tr>
</tbody>
</table>

- **Compact Sedan**: Gasoline consumption with conventional fuel.
- **Midsize Sedan**: Gasoline consumption with conventional fuel.
- **Midsize SUV**: Gasoline consumption with conventional fuel.
- **Fullsize SUV**: Gasoline consumption with conventional fuel.

This means fuel can be 100% ethanol ---no change in current supply.

Increasing Hybridization →
Results: EPRI-Car Co’s.-DOE Labs study “Comparing Hybrid Electric Vehicle Options”– Conv, and hybrids P0, P20, P60 for a 1500kg car

Based on $1.50/gallon
Gasoline—6cent/kwhr electricity

Fuel Costs (cents/mile)

Vehicle Fuel-cycle

CO2 Emissions (g/mile)

Fuel Economy (mpg)

Smog Precursor Emissions (mg/mi)
Annual Gasoline saved for the average car & Truck, Conv., HEV, PHEV’s as a function of AER on **FUDC** (suggested standard for AER specification)

Conventional car uses 740 gals gasoline/yr.

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**Gasoline Saved for Different All-Electric Ranges**

- **Annual oil savings for 10% fleet penetration (PHEV-40) is about 300 million barrels saving 4.5% of the US oil used/year—Enough to Eliminate Middle Eastern Oil Imports!!**
- **Use of Ethanol in PHEV’s further increases oil savings!!**
- **The best concept is to construct PHEV’s with flex fuel capability.**
The PHEV can be used to balance the Electric Grid-Integrating electric power and transportation energy sectors-20% penetration of the total car population—There’s enough generating power for ½ Fleet with no more power plants!! --20 years at least!!

<table>
<thead>
<tr>
<th>Energy available for the grid (V2G)</th>
<th>0 Mwh</th>
<th>Consumption without V2G</th>
<th>35300 Mwh</th>
<th>Total Base load before</th>
<th>24960 Mwh</th>
<th>Total Peak Power before</th>
<th>10340 Mwh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use for recharging vehicles</td>
<td>4 Mwh</td>
<td>Consumption with V2G</td>
<td>37068 Mwh</td>
<td>Total Base load after</td>
<td>34560 Mwh</td>
<td>Total Peak Power after</td>
<td>2508 Mwh</td>
</tr>
<tr>
<td>Nb of vehicles</td>
<td>12500 #</td>
<td>Consumption increase</td>
<td>5.01 %</td>
<td>Base load increase</td>
<td>38.46 %</td>
<td>Peak Power decrease</td>
<td>75.74 %</td>
</tr>
</tbody>
</table>

- Base load (MWh)  
- Peak Power (MWh)  
- V2G Power (MWh)
Trans-Canada Plug-In Highway

- Uses hotels and motels across Canada with block heater plugs in the parking lots.
- Incentives for all hotels to install parking lot plugs.
- Each plug displaces two to three gallons of gasoline a day.
- Plugs can have the electric grid, wind or Solar as the energy source.
- Customer benefits: fuel costs are less than $\frac{1}{4}$ when using renewable electricity.
• Need to convince the car companies that the public demands this kind of vehicle for energy security, flexibility and an improved society.

• Public needs to demand of the car companies to build large battery packs cars with these features.

• One company needs to construct the first 100 or more demonstration vehicles to provide the public, government and industry with a fleet of vehicles for manufacturing cost, feasibility and Nationwide energy savings evaluation.

Political & Public support is needed for the PHEV concept to motivate the car Companies to build these cars and trucks
Purpose of PHEV is **Zero Carbon**
Energy use in our Society

- We heard The Doomsday talk this morning but as an Engineers we want to create solutions!!
- Started the work 30 years ago on PHEV
- We have created solutions but now need to get these solutions into mass production and into the hands of the public by convincing investment from the government, auto/truck and oil industry
Long range (100km) AER and Plug-In HEV and it’s advantages

- 2X to 5X fuel/energy economy, 80% to 90% fewer mechanical parts. Weight equivalent to CV
- Uses Up to 90% wall elect. energy - 10% liquid fuel annually.
- Higher performance than conventional vehicles possible.

Engine about 1/3 the CV and advanced batteries lasting the life of the Car. (Li or MHD)
The advantages of a large battery pack

- Provides ability to travel at Zero Emissions and low Noise for a substantial part or all of the vehicle’s daily use.
- Does not have to be charged since the gasoline or diesel engine is always there to automatically take over when the charge gets below a set State of Charge (SOC), like 20%.
- **1/10th to 1/3 Fuel cost** for a PHEV running on Electricity obtained from the wall plug. $0.25-$1/eq gal
- **People will plug these cars in!!**
- **Batteries can be used to store energy from Small water, wind and solar systems as well thus also making these systems More practical now! And even lower cost/mile!! Conv cars 14c/mi---Solar PHEV 2c/mi!!!**
Wind mills that can use PHEV batteries to store generated energy rather than “waste it” or reducing power plant efficiency
Wind Turbine issues

- When the wind blows, electricity generated must be used or wasted. Generating H2 has a lot of loss!!!
- Wasting electricity by heat or throttling the wind mill is not cost effective because you are wasting a resource and not getting payback as quickly as you can. Feeding to the grid means throttling NG
- Ideal for charging batteries of PHEV’s can again displace gasoline use which is much more cost effective than trying to supplement electricity at 4 cents/kwhr. (Will go 3 to 4 times farther than H2) –means H2 “bar” is now 3 times higher!!
  - A 10 kw wind mill would be about 10 meters in diameter and could cost about $10,000. thus a payback time of about 3 to 4 years if used for charging PHEV cars. Another Industry!!
Wind farms on the sea or Prairies can also use large collections of PHEV’s for temporary storage.
Large Utility Wind and Solar can use the PHEV en-mass

- Concept of PHEV can be used with Small home and office Wind and Solar for private user Energy Independence---2kw to 500kw
- Utility Wind and Solar can be used to charge the PHEV en-mass at 1mw to 10mw but requires distributed energy management systems
- Electric grid is used for energy integration at a low power level (1-2kw) and locally only!! A new use for the electric grid!!
660cc gas + 100hp E/M + CVT = performance of a 3L + Automatic Trans
A Building Block for Sustainability using a Technology path with no change in Energy infrastructure

- The **Plug-In Hybrid Electric Vehicle PHEV** with enough batteries to provide 30 to 60 miles of all electric range. From 15 to 30 kWhrs of batts-SUV.

- **Night time charging for batteries** from base electric plants and **daily charging with solar and wind or other renewable like water**.

- Use of vehicle battery energy for home, office, and factory electricity use including cooking and Air Conditioning--building El. energy supply.

- **Day time charging with renewable sources**.

Daytime use of the PHEV batteries to reduce Daily Peak Electric needs, Spinning Reserves, and Voltage Regulation for The Electric Utilities
The Powertrain Concept of a Plug-In Hybrid Electric Vehicle for trucks up to 4 tons. Gasoline or Ethanol

Batteries under the floor

No interior space needed for batteries. Overall vehicle weight is the same due to smaller engine and transmission.
Don’t step back in technology
When we move forward to sustainability!!! Here storage is in Animal stomachs and meat
Each line represents market potential versus price for a simple market in 2010 where HEV 0 and conventional models are available in each mid-size model, or HEV 20 and conventional models compete. The six points on each line are calculated with a common methodology. The two enlarged points on each line show the base case range (before government or automaker incentives). The base case range assumes costs using 100,000 HEVs per year and also reflect different methods of estimating the retail price estimate.
Willingness to pay for alternative fuel options

By regions:

<table>
<thead>
<tr>
<th>Region</th>
<th>Willingness to Pay</th>
</tr>
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<tbody>
<tr>
<td>NE</td>
<td>$9200</td>
</tr>
<tr>
<td>MW</td>
<td>$7400</td>
</tr>
<tr>
<td>S</td>
<td>$8600</td>
</tr>
<tr>
<td>W</td>
<td>$11,000</td>
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Average: **$9300**

Conclude: People consider alternative fuel vehicles in a different category from conventional cars!! Therefore we are not in competition with conventional cars until we reach these thresholds!! Thus they can afford a PHEV-60.
Local energy feed back only by V2G

P=power plants
S=Substations
V2G=Cars feeding grid
Will the Car & Oil comps, Government and the World like the idea??

• Car companies-YES because they have a chance to get ahead of outside competition
• Oil companies-Yes because they can make more money by taking the lower marginal consumption in the US and selling it for more money on the open World market
• The US Homeland security Office-YES because it can reduce middle east imports quicker than any other alternative.
• The World-YES because it shows the way to an otherwise Doomsday Wedge!!
Summary and Conclusions

- PHEV’s are a low cost solution to environmental & Energy Security problems and could provide high profits and employment for early investors.
- These vehicles can be brought to production now with little investment in development. No change in manufacturing and fuel infrastructure is needed!!
- PHEV’s can begin the integration of Society’s Energy systems to move toward an all Renewable electric society by reducing petroleum consumption by 50% to 100% Now.
- Can be an interim solution for the next 50 years to move society toward development of new vehicle and energy concepts such as H2 Fuel Cells or whatever???? But “Bar” is 3X higher!!
Summary and conclusions Continued

• PHEV’s can get us out of IRAQ and the Middle East to provide National Security faster than any other solution Now!!
• PHEV’s using Water and other Renewable energy and Bio fuels--can begin our transition to zero oil consumption and CO2 Now.
• PHEV’s will allow us to integrate our transportation and stationary energy systems for much higher efficiency thus drastically reducing our per capita energy consumption.

Goal is to reduce our per person consumption of Fossil energy Oil and Coal while Improving our lifestyle with greater comfort and productivity.
$200,000 DaimlerChrysler PHEV Sprinter Van
Where are these vehicle??

<table>
<thead>
<tr>
<th>Bullet Points</th>
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</thead>
<tbody>
<tr>
<td>• This is a <strong>doable now</strong> technology with no new technology breakthroughs needed for implementation. Only the Mind set of People!</td>
</tr>
<tr>
<td>• The incremental cost over conventional cars can be less than 15% and today’s components, suppliers are now available!</td>
</tr>
<tr>
<td>• <strong>The car companies need to be convinced that people will buy if they build these vehicles</strong></td>
</tr>
<tr>
<td>• The price of gasoline may do it!! Since elect at 8 cent/kwhr is equiv. to less than 1$/gal gasoline in a PHEV!!</td>
</tr>
</tbody>
</table>
Car company and most research HEV’s today

- Small battery pack must be kept within a narrow charge range for life. Lacks robust operation.
- Fuel economy up to 50% better. 1.5X, **Uses no electric energy.** Batt.≈1.5kwhr
- Engine downsized 10% to 20% for equal performance.
- Low power electric batts and motor compared to long range AER.
Medium range AER, 30 KM, HEV for lower Fuel use and emissions

- This size battery pack provides better fuel economy and all of the features of the HEV 0.
- Liquid fuel & electric grid energy use can be about 50/50. Batt. ~9kwhr
- Engine about 2/3 CV.
- Battery life 120k km to 160k km (Mhd Ovonics).
Additional uses for the large battery systems

• Batteries can be charged at night thus **balancing the electric grid** and raising the base load and reducing peak load generation with rolling reserves, thus reducing the cost of electricity to everyone!!

• Electric charging of the PHEV should be done at a **low power level, 1.5 to 2kw** , so there is no need for special charging stations. Standard 120 V GFI outlets will do. The standard Block heater plugs in some towns will do just fine!

Gasoline reduction on an annual basis can be up to 80% to 90% . **Therefore;** The liquid fuel for these vehicles can easily be Ethanol/Bio-Diesel. Thus Reducing **Petroleum Consumption to ZERO NOW!!** Without having to go to H2!!
New 300hp UCDavis CVT in Evaluation by independent auto supplier companies-Efficiency 95%+ durability 200k mi+
Year 2000 100kw gas, 150kw E/M, CVT powertrain for SUV’s & trucks, 29kwhrs batts for 60 mi. AER
Step Van or Minibus 6Ton Chassis
for Enova PHEV with 45 mi AER

56kwhrs batteries

2.5 L Diesel

New UCDavis
300 hp CVT

80 kw electric motor/gen
EPRI study: Fuel, Running, Component and Purchase Costs, and Market Potential for Midsize 1350 kg car

Fuel Cycle Energy Use (kWh/mi)

- Natural Gas
- Petroleum

Fuel Cycle Energy Use for various vehicle types:
- CV
- HEV 0
- HEV 20
- HEV 60

Component Retail Price Equivalent

- On Vehicle Charging System
- Energy Storage System
- Electric Traction
- Accessory Power
- Transmission
- Engine + Exhaust
- Glider

Average of Base and ANL Methods

Annual Gasoline Use for Various Vehicle Types

- CV
- HEV 0
- HEV 20
- HEV 60

Market Preference for HEV over CV

- Low
- ANL
- Base
- High

Gallon per vehicle

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
UCD V2G project with “CNCI” and BART

- To explore and develop new concepts for power management and control for distributed energy feedback at low levels of power---Low cost system to the customer or consumer.
- To demonstrate operation of the grid system V2G computer controller necessary to manage and control energy flow.
- To demonstrate economics of V2G on a small controlled grid.
- To create an energy “BARTer” system for Win---Win.
Large battery Plug-In HEV’s in remote locations and Civilian Public service

- Having a large number of “portable gen-sets” for a base, gives redundancy and reliability for electric energy. Some are charging, some supplying electricity. No need for separate gen sets!!
- Large battery PHEV’s can provide reliable field electric generation from multiple sources.
Summary and Conclusions

- US DOE needs to fund 1500 fully designed Demonstration PHEV vehicles systems to show manufacturing feasibility and costs analysis including supply chain development for:
  - Passenger cars,
  - Minibuses, delivery vans
  - Demonstrate V2G and Renewable Energy PHEV projects integrated with solar and wind to develop needed hardware and software to take advantage of “free” energy storage.