The Plug-In HEV (PHEV) to reduce US dependency on oil and coal for both stationary and transportation 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, offices & factories.
- Integration of **small** 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 technology and infrastructure

A Building Block for Sustainability using a Technology path without changing The Energy Infrastructure:

- The **Plug-In Hybrid Electric Vehicle PHEV** with enough batteries to provide 10 to 60 miles of all electric range **(AER) measured on the FUDC only.** From 5 to 30 kwhrs of batts- for SUV's.
- **Night time charging for batteries** from base electric plants and **daytime** charging with **solar**, **wind** or other **renewable** energies
- Night time use of vehicle battery energy for home electricity use including Cooking, Air Conditioning and Refrigeration.

Daytime use of the PHEV batteries to reduce Daily Peak Electric needs, Spinning Reserves, and Voltage Regulation for The Electric Utilities, V2G

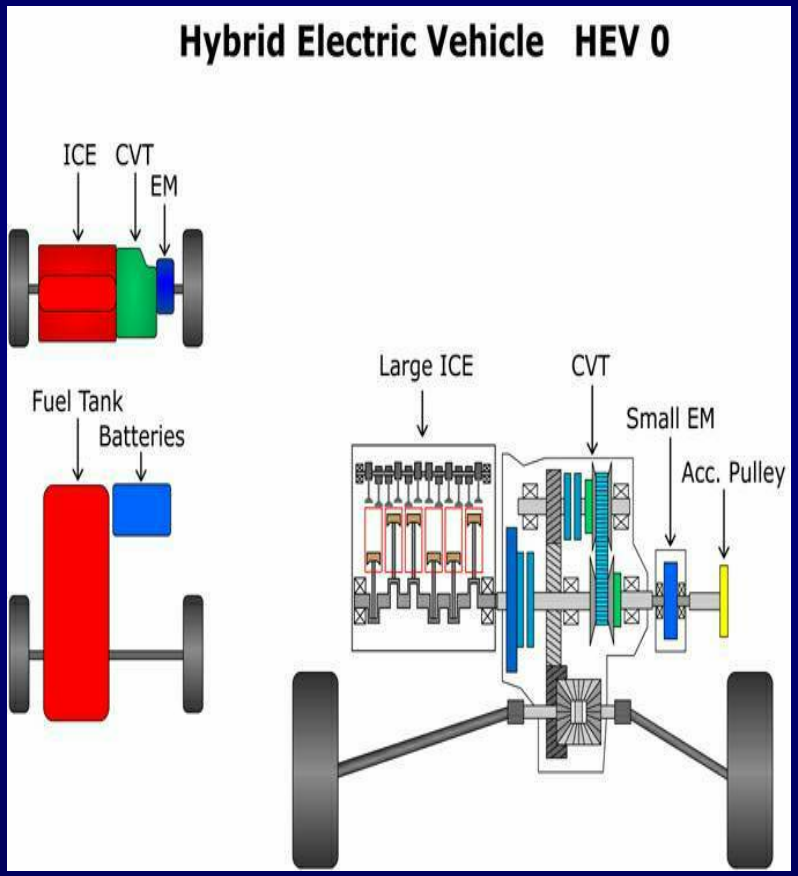
What is a Plug-In HEV??

- The Plug-In HEV is like a Toyota Prius except it has a **smaller** engine and a **larger** electric motor and **larger** battery pack and **a 120 V plug** to the wall to charge the batteries!! No need for quick charge!
- This combination allows the vehicle to have **better** fuel economy, **higher** performance, and All Electric Range **(AER)** up to 60 miles on the FUDC 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 with elect from powerplants or from renewable energy such as solar or wind If you don't plug-in you simply use more liquid fuel. Performance is independent on Battery SOC!!

Don’t step back in technology When we move forward to sustainability!!!

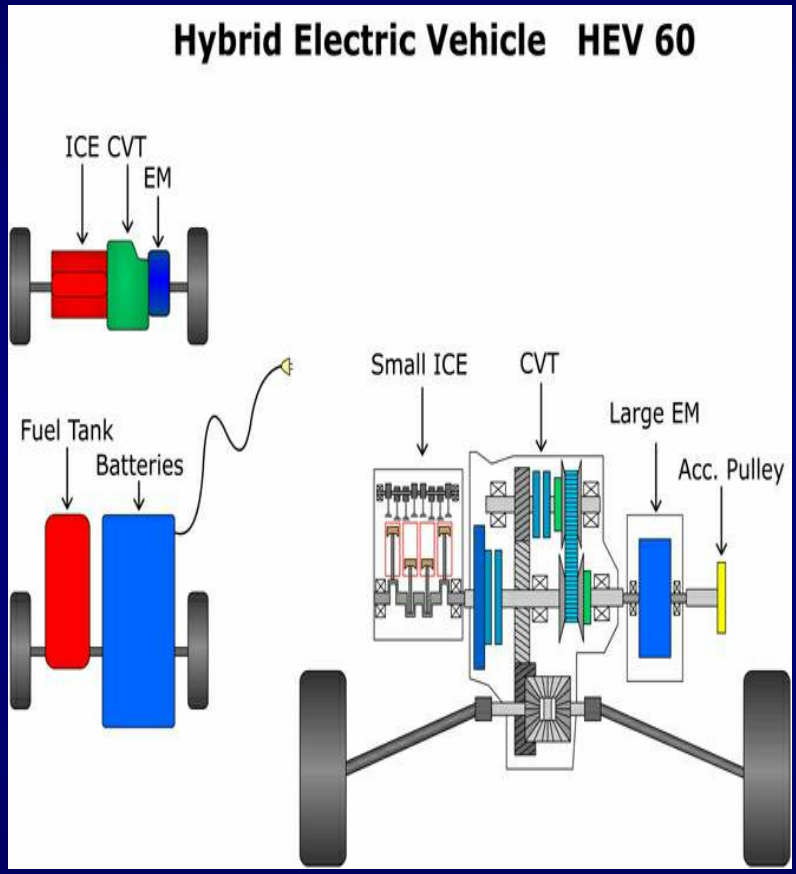
Car company and most research HEV's today

- 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 .



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 <u>1/3 the CV</u> and advanced <u>batteries lasting the life of the Car</u>. (Li or MHD)

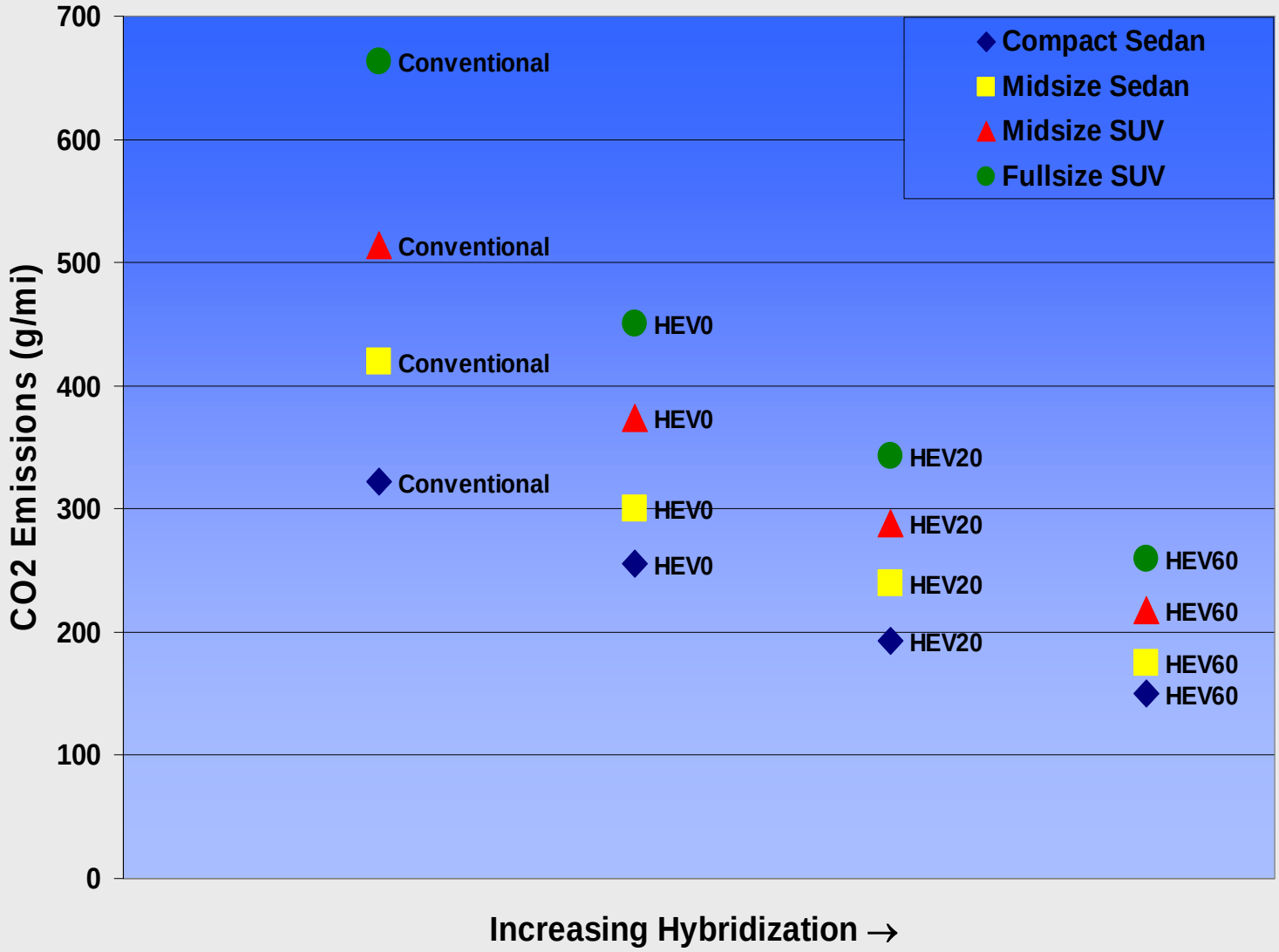
60 mile AER PI-HEV vehicles with CVT's constructed at UCDavis to show technology is here today!! Supply Chain for parts has already been Developed!!

EV1-PHEV
80mi AER, 80mpg
Auto Mech. CVT

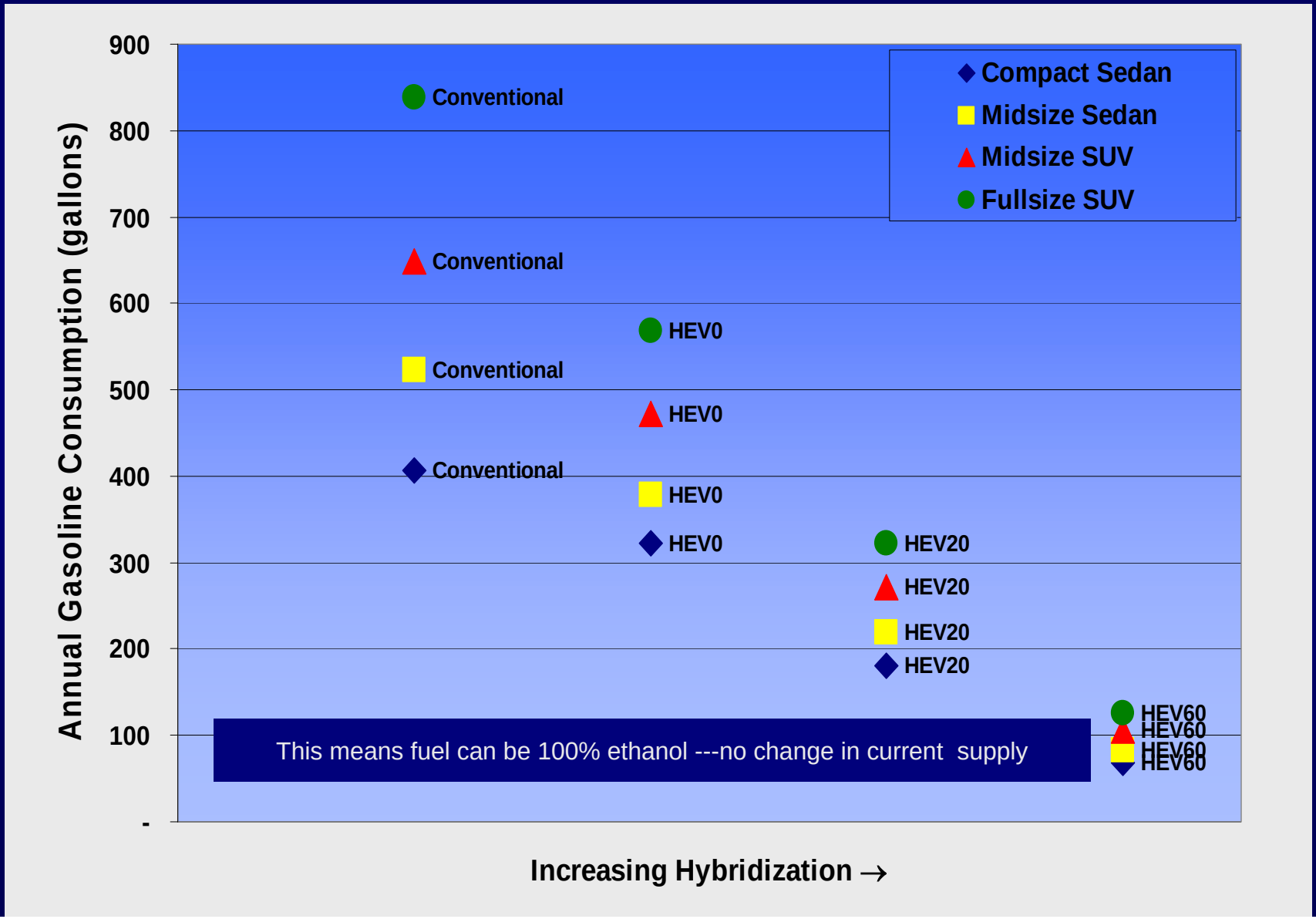
'94 Mercury Sable
60 mi AER, 58 mpg
Automatic mechanical CVT

2000 Suburban
60 mi AER, 28 mpg
New automatic CVT
Being installed

Greenhouse Gas Emissions for all light duty cars trucks--gasoline and conventional elect-No solar



Annual conventional Gasoline Consumption for 12,000 miles of driving-all L/D vehicles----No E85



What are the technical and social BARRIERS to widespread adoption of PHEV's

- Convincing the Auto and Oil companies that the PHEV is beneficial to their well being and will make them much more competitive today!
- Ethanol-(Cars but no Infra), PHEV-(Infra but no cars)! **Marry** the two concepts for largest quickest Impact for **oil reduction**.
- Use of PHEV to integrate with *roof-top Solar and Wind* into Vehicle-Home-Office for new domestic Jobs and for an improved cleaner **Zero** CO_2 and emission Society.
- Understanding that PHEV's reduced Vehicle **"fuel"** costs (15c/mi to less than 3c/mi @220 whrs/mi)

What are the technical and social BARRIERS to widespread adoption of PHEV's---Continued

- The acceptance of home refueling and safety measures needed to insure safe operation of the house energy systems—Davis, CA--garage EV charger plug ordinance passed!
- The change of habits!! Plug –In your vehicle to save most of the "fuel" costs, reduces Gas.Sta. trips to 5/yr vs conv. cars at 35/yr.
- The integration with existing Electric Grid – Use GridWise metering developed by DOE.
- The idea that we can move toward zero carbon society **NOW** with **NO** lifestyle sacrifices or new infrastructure development!

ovonic solar

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 30miles of driving for each hour of sun for a mid size car. (Cost-$8/watt-$3/watt rebate=$5/watt. New systems 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!!

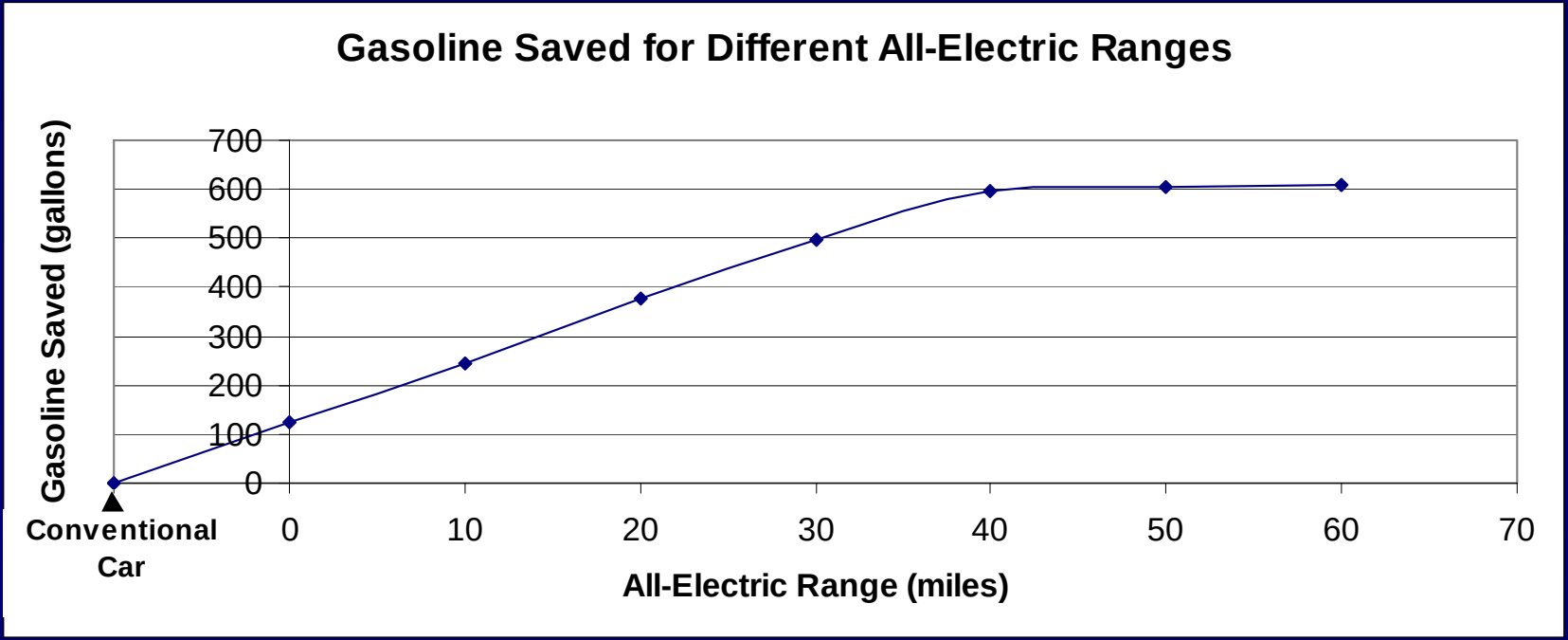
Wind mills that can use PHEV batteries to store generated energy rather than “waste it” or reducing power plant efficiency

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!!

Annual Gasoline saved for the average car & Truck, by Conv., HEV, PHEVs as a function of AER on **FUDC** (suggested standard for AER specification)

Conventional car uses 740 gallons of gasoline/yr-for 15000mi/yr driving



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 Solar, Wind and Ethanol in PHEV's further increases oil savings!!

The best concept is to construct PHEV's with flex fuel capability and add Solar and wind generators to homes, offices, and shopping centers

Is there an Optimal AER that allows drivers to meet their daily needs??

- The average driver uses his car for about 40 miles/day and drives 15,000mi/yr. Thus, a 40 mile AER would satisfy about 50% of the driving public. This can be done Today!
- A 40 mi AER in ½ the US fleet 'could' reduce oil to ½ current use.
- ½ US fleet penetration of PHEV's would require ~20 years since new cars represent less than 10%/year –No effect on the electric grid generation at this level, Solar & Wind makes it better!

How long will it take before we see PHEV's in the marketplace?

- 2 year demonstrations and demand creation & Dvlpmt.—government support is needed!!
- One more year for production Launch
- 3 years total for volume production at about 50,000/year-with 2 OEM's
- 5 years- 500,000 to 1million /year by 3 to 5 OEM's across 3 platforms
- 10 years -7.5 million cars/year (½ the new car fleet). The driver for PHEV introduction is liquid fuel costs & Gov Incentives-Tax breaks and subsidies for 3 to 5 years.

How large an Impact on oil consumption could the PHEV's have in the next ten years??

- Likely scenario: Car companies could introduce the PHEV and increase the AER from 10 miles to 60 miles in ten years.
- Oil consumption would drop depending on demand and sales volume. As the price of gasoline rises the demand could rise in 5 years to ½ the new car fleet. Replacing 25% of the fleet of cars with (PHEV 10 to 60) by 2016.
- Oil use could be 12 to 20 % less in ten years. Ethanol or bio-fuels, Solar and Wind will lower it more.

Conclusions about PHEV's

- R&D of PHEV technology has been done by UCDavis and is ready for pre-prod-Demonstrations to convince people and industry on it's benefits and value to society and US. We've built 8 concept cars!
- Need 25 to 50 pre-production completely engineered and properly integrated systems on existing car and truck platforms with parts suppliers to show Mass Manufacturing capability can be done NOW.
- Need to develop Standards for Design and Tests by SAE and EPA/CARB to direct the car companies.
- The PHEV with "small" Solar, Wind, and Ethanol can move the US toward **zero** oil, coal and CO_2 Today!!
- Improved lifestyle and much more energy efficient Society with **no new infrastructure needed!!**

Appendix and supporting slides

- What are some of the production issues?
- Definitions and infrastructures
- Cost increments for HEV, PHEV, Diesel
- Potential sales volume vs costs—Are people willing to pay for a PHEV??
- Vehicle back to the grid, V2G
- Total energy reduction by PHEV
- More Conclusions

What major R&D&D work remains for PHEV technologies and prioritization??

- R&D mostly done! **Pre-production Vehicle <u>Demonstrations</u> and component <u>Supply chain</u> is Needed--Batteries!**

<u>Priorities for a 100 veh. Demo Fleet:</u>

1.33 Midsize highest volume car

2.33 Minivan or small SUV

3.33 Compact car like a Prius but better!

- To obtain user feedback from customers & for manufacturing Infrastructure and supply chain devel. & market assessment and pricing.
- Integrate Electric Utilities with PHEV's & new renewable energies—Wind and Solar

What are the largest obstacles preventing widespread commercial applications & steps needed to -- Ameliorate?

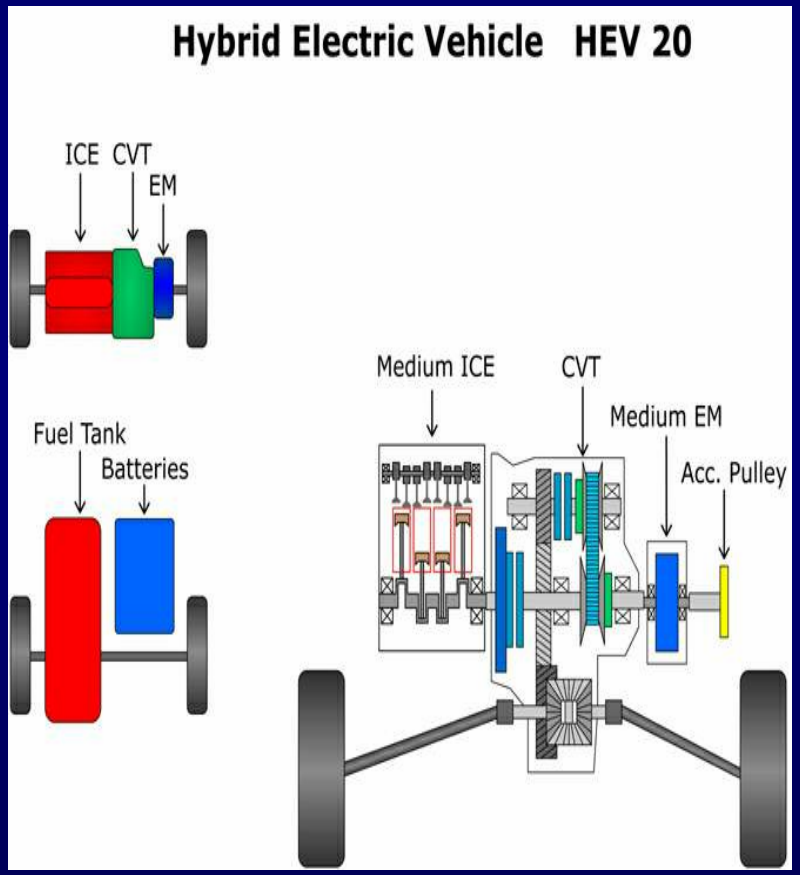
- Automotive and Oil industry **Inertia**.--Demo. Vehicles by outside vendors in coop w/car-co
- Concept Value Judgment--PHEV is more than transportation-It **integrates** with electric system, Therefore worth more!
- Battery life and Power electronics costs--development of a supply chain.
- Sealed and durable high voltage systems--Demo. and development.
- Need for New National Testing, & Standards for evaluation of energy use and safety procedures by USEPA, National Electric Code, UL, etc. Defin:All Electric Range AER

Do the Fed's support PHEV now? What can the Fed's and States do to accelerate production development of PHEV's

- Some past support from DARPA and Student Competitions (DOE) used for R&D by UCDavis
- Gov. support needed **today** to build a fleet of 100 **advanced** **fully engineered** PHEV's with all electric ranges from 10 to 60 miles on three of the most popular platforms with one or two of the American OEM's in 2 to 3 years, and develop the parts supply chain—EDI is setting up to do this!
- Cost: about $50 million total needed.
- With fleet/private buyers at $80,000/car, govmt cost would be about $40 million.

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 m to 160k m (Mhd Ovonics).



Where are these vehicle??

- This is a **doable now** technology with no new technology breakthroughs needed for implementation. Only the Mind set of People!
- The incremental cost over conventional cars can be less than 15% and today's components, suppliers are now available for most parts!
- **The car companies need to be convinced that people will buy if they build these vehicles**
- The price of gasoline will do it!! Since elect. at 6 cent/kwhr is equiv. to 70 cent/gal gasoline in a PHEV!!

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 can 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.

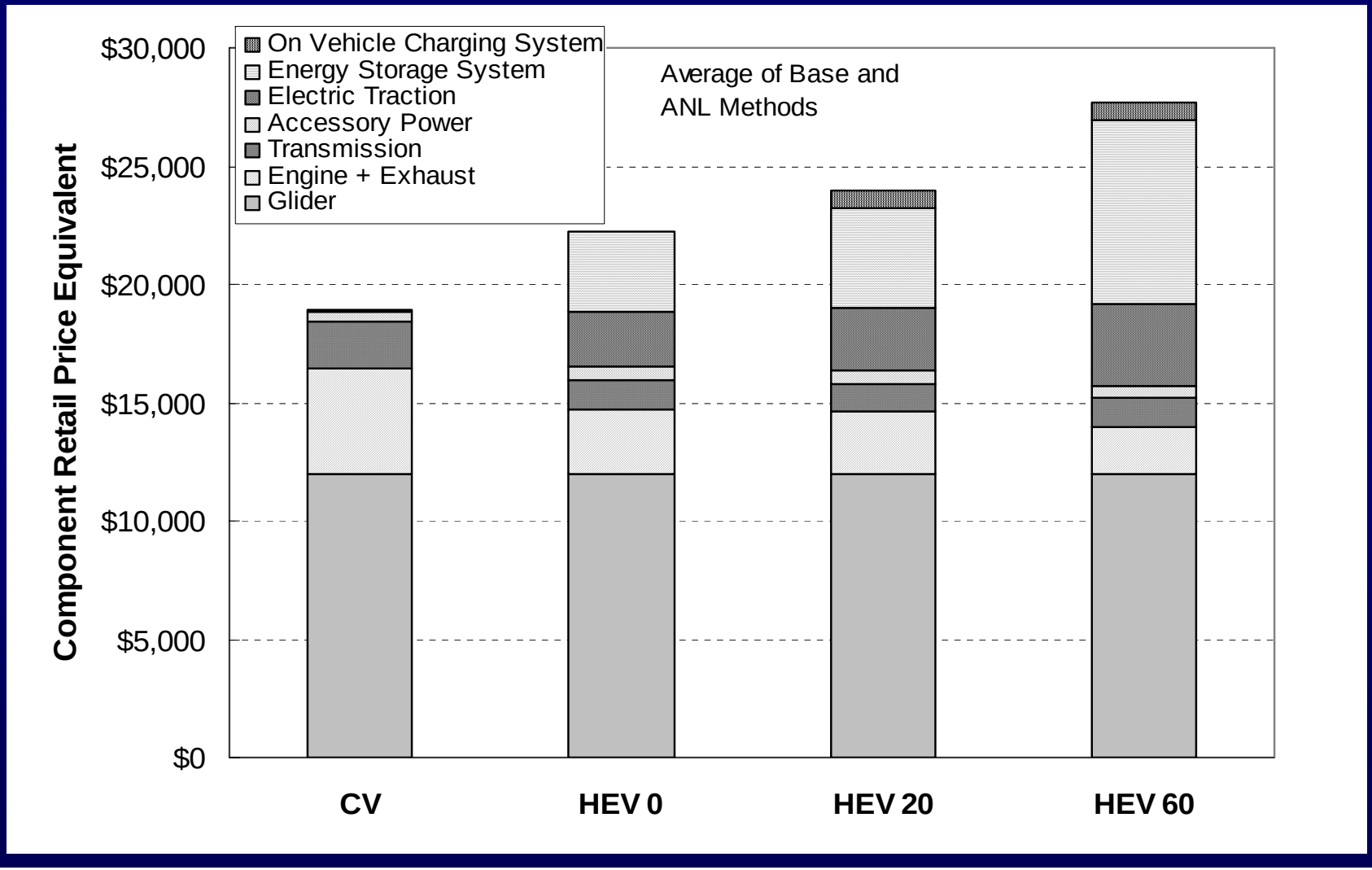
Gasoline reduction on an annual basis can be up to 80% to 90% . **Therefore;** The liquid fuel for these vehicles can easily be Ethanol/Bio-Diesel. Thus Reducing Petroleum Consumption to ZERO NOW!! Without having to go to H2!!

What Energy infrastructure are we talking about?

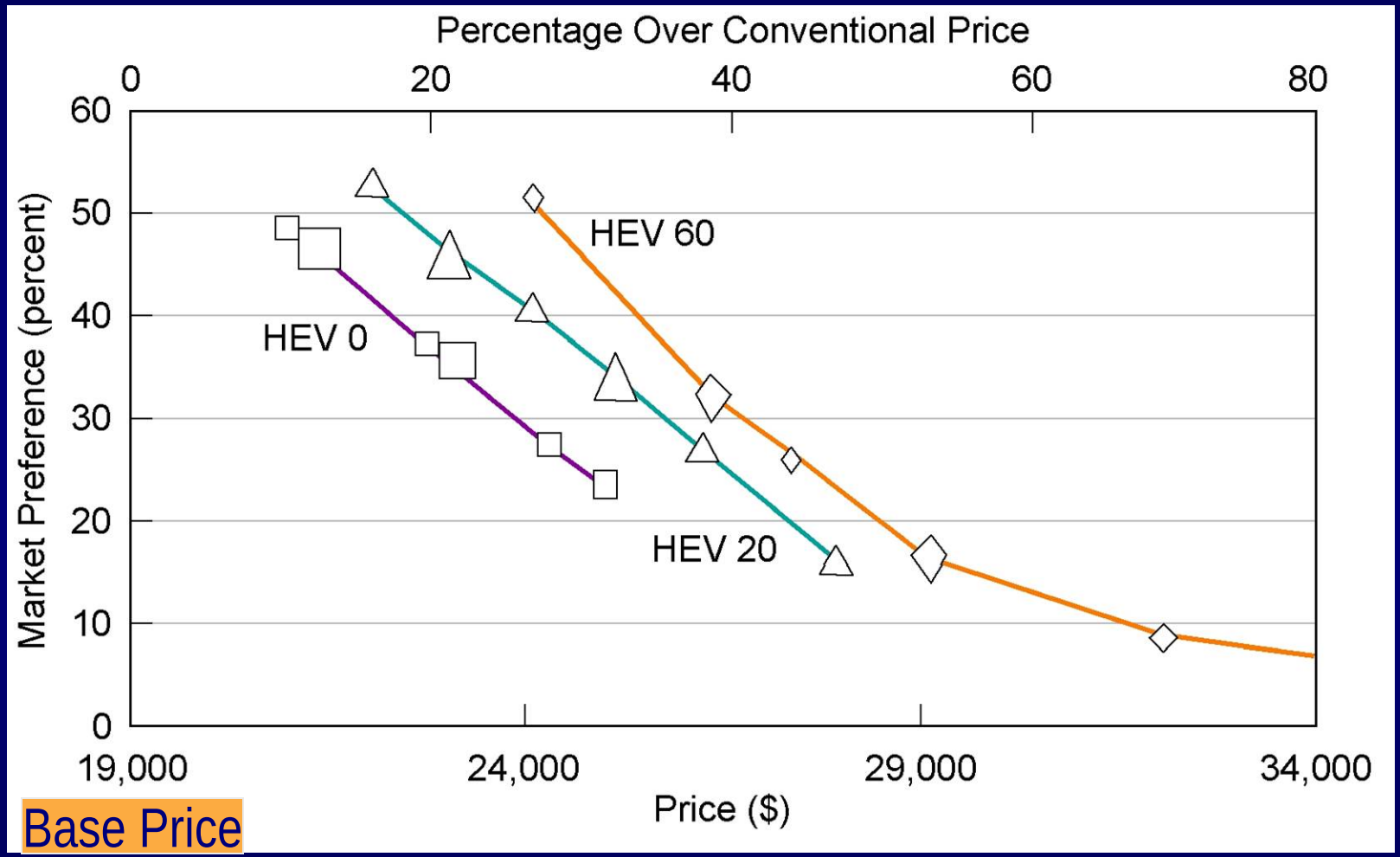
- The current energy infrastructure that we have in our society today + Computer controls.
- 120v Electric GFI plugs in the home and on the streets with energy management chip as in “GridWise”.
- Gasoline and Diesel stations
- Home garages with 120v GFI plugs and energy Chips
- Distributed energy stored in batteries of the PHEV cars.
- Note PHEV cars all have energy management systems already internally 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.

Incremental costs of a Conv. Veh., CV, HEV and ranges of PHEV's Based on the EPRI study of 2001 (lower costs today!)



Mid-size HEV car Market Potential vs. Price



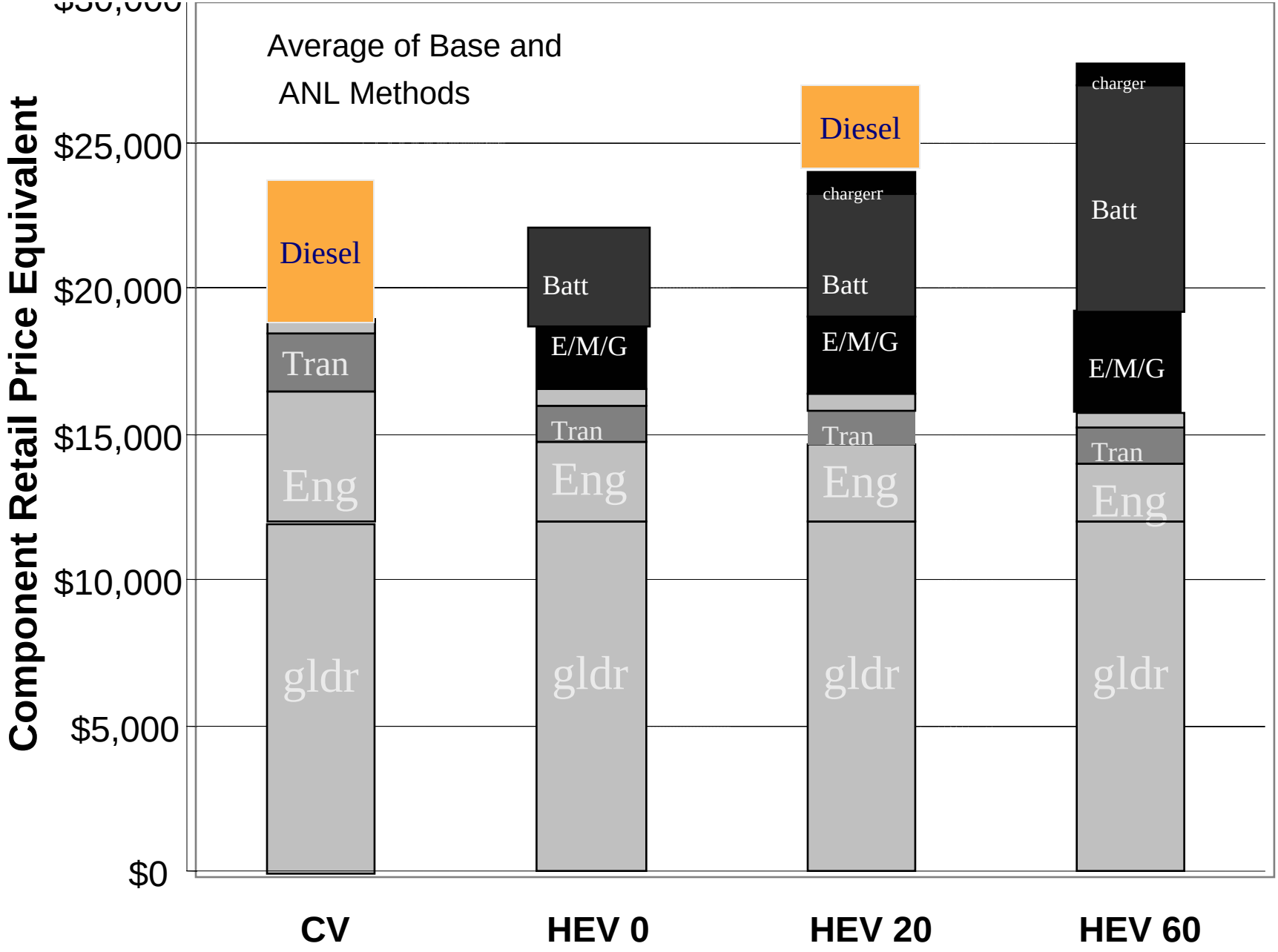
Each line represents market potential versus price for a simple market in 2010 where HEV 0 and conventional models are available in each mid-size model, or HEV 20 and conventional models compete. The six points on each line are calculated with a common methodology. The two enlarged points on each line show the base case range (before government or automaker incentives). The bas case range assumes costs using 100,000 HEVs per year and also reflect different methods of estimating the retail price estimate.

Latest incremental cost survey for Alt fuel veh. (PHEV)---Washington Post 4/29/06

Willingness to pay for alternative fuel options.

By regions:

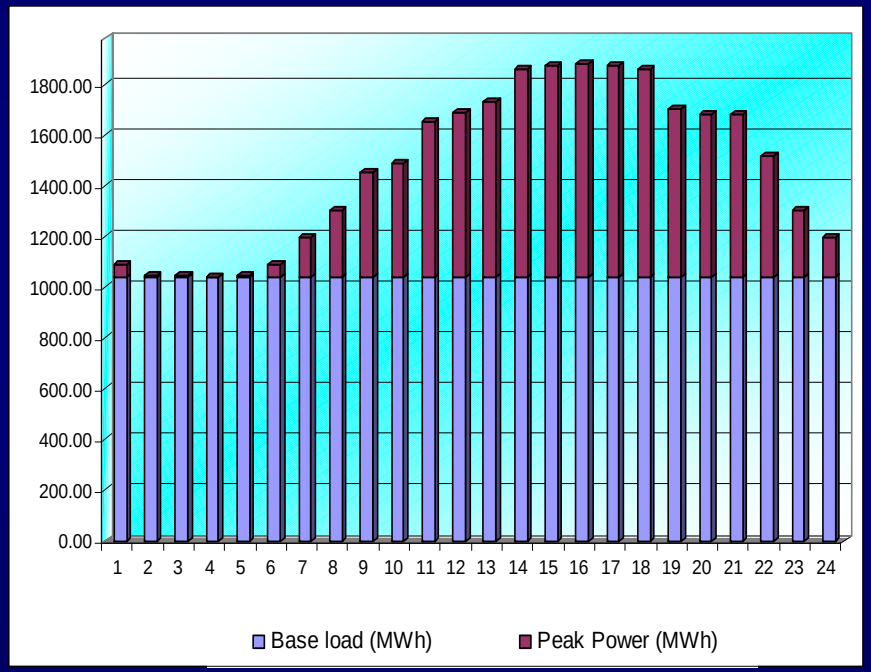
- NE $9200
- MW $7400
- S $8600
- W $11,000 Average **$9300**
- Conclude: People consider alt. Fuel vehicle in a different category from conventional cars!! Therefore we are not in competition with conventional cars until we reach these thresholds!! Thus they can afford a PHEV-60

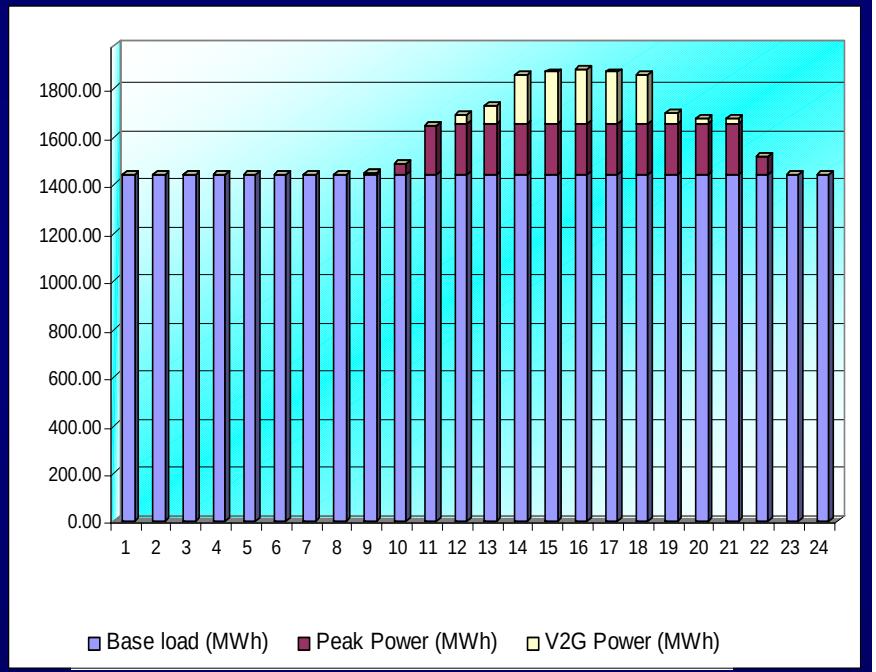


Incremental cost of Diesel compared to Hybrids. (Diesel +P20=P60)

Grid-Integrating electric power and transportation energy sectors-20% penetration of the total car population-

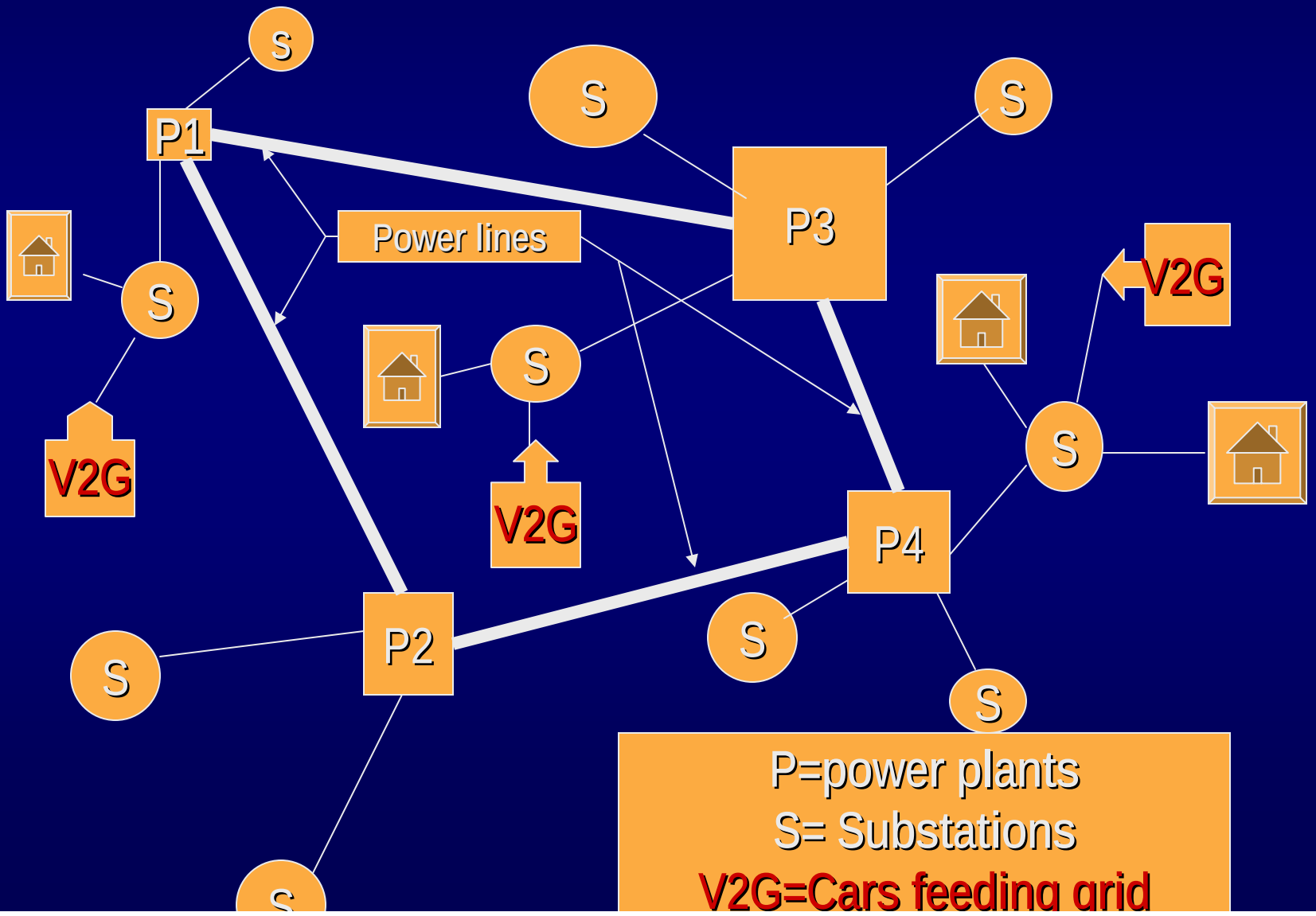
There's enough generating power for ½ Fleet with no more power plants!! --20 years at least!!





Energy available for the grid (V2G)	**0**	Mwh	Consumption without V2G	**35300**	Mwh	Total Base load before	**24960**	Mwh	Total Peak Power before	**10340**	Mwh
Energy use for recharging vehicles	**4**	Mwh	Consumption with V2G	**37068**	Mwh	Total Base load after	**34560**	Mwh	Total Peak Power after	**2508**	Mwh
Nb of vehicles	**125000**	#	Consumption increase	**5.01**	%	Base load increase	**38.46**	%	Peak Power decrease	**75.74**	%

Local energy feed back only by V2G



Total Energy consumption by using the PHEV as the center Piece

- Use water, **home** wind, and solar to charge batteries thus making new businesses. Driving fuel costs to 0
- Use vehicle batteries for emergency **home** energy.
- Use PHEV to balance electric grid to reduce electric power transmission costs.
- Burn ethanol from celluloustic biomaterials or bio-Diesel instead of petroleum derived fuel.
- The US can be free of oil/coal in less than 50 yrs!!

Use PHEV for all energy supplied by renewable sources To Eventually Reduce per capita petroleum energy to near Zero while providing an even More advanced lifestyle.

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 electric society by reducing petroleum consumption by 50% to 100%.
- 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.
- PHEV's will allow us to integrate our transportation and stationary energy systems for much higher efficiency thus reducing our per capita energy consumption.

Goal is to reduce our per person consumption of Fossil energy while Improving our lifestyle with greater comfort and productivity

Summary and conclusions continued

- Need to convince the car companies that the public demands this kind of vehicle for energy security, flexibility and an **improved** society and profits!!
- Public needs to demand to the car companies the features possible from these large battery packs. **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 and feasibility evaluation.--- **EDI**--- just formed to do just this!

Political & Public support **is needed for the PHEV concept to motivate the car Companies to build these cars and trucks**