

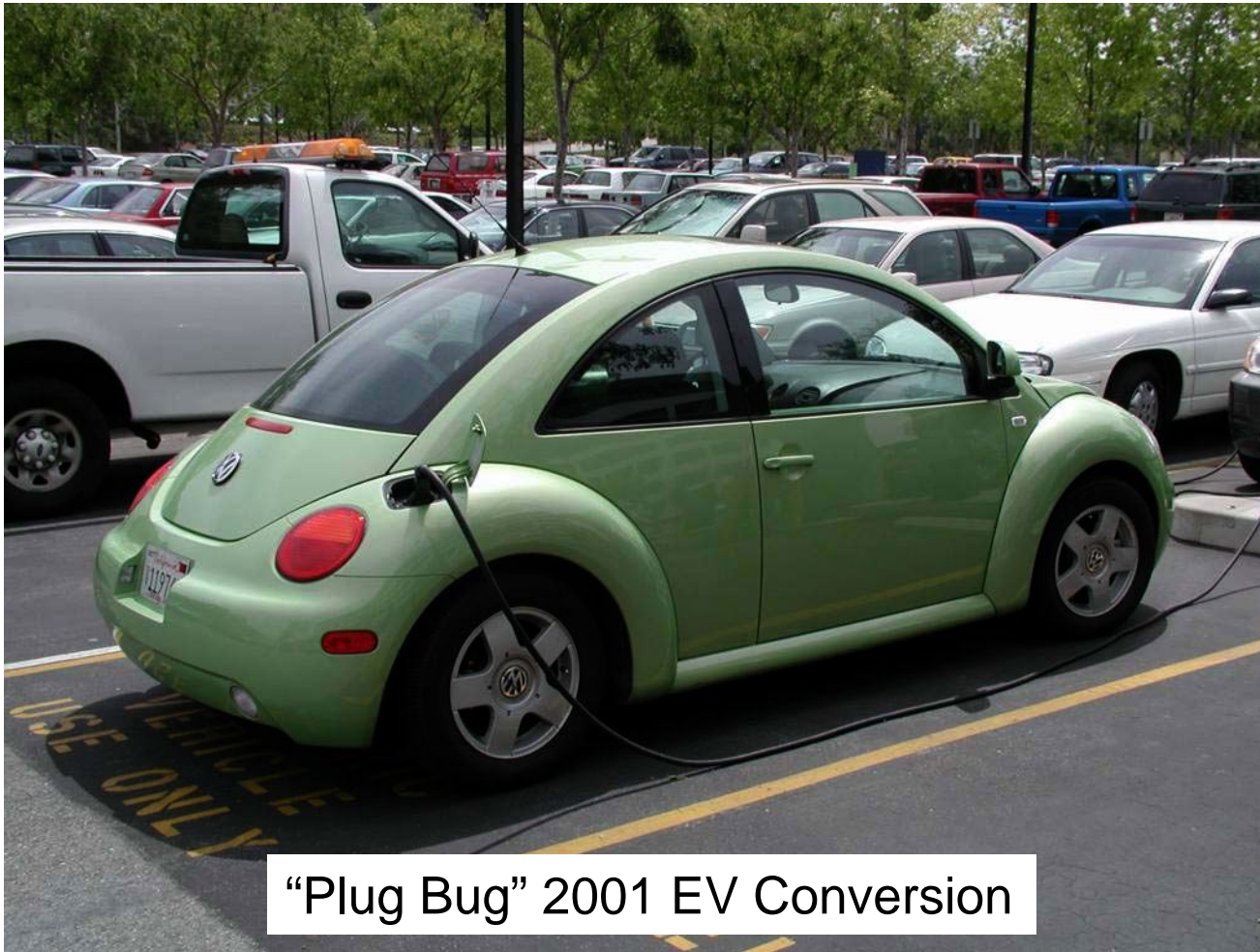
Connected Cars: Battery Electrics & Plug In Hybrids

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The Seattle Electric Vehicle to Grid Forum
V2G Technical Symposium
June 6, 2005



The Connected Car



- Plugs in to the grid
- Refuels while parked
- Uses existing infrastructure
- Adds to energy diversity
- Presents off-peak load
- Provides dispatchable power asset

Major Automotive Transformations

- 1900s - horses → cars
effectiveness
- 1970s - dirty engines → clean engines
emissions
- 2000s - mechanical → electro-mechanical
efficiency
- ? 2010s - unconnected → connected
energy

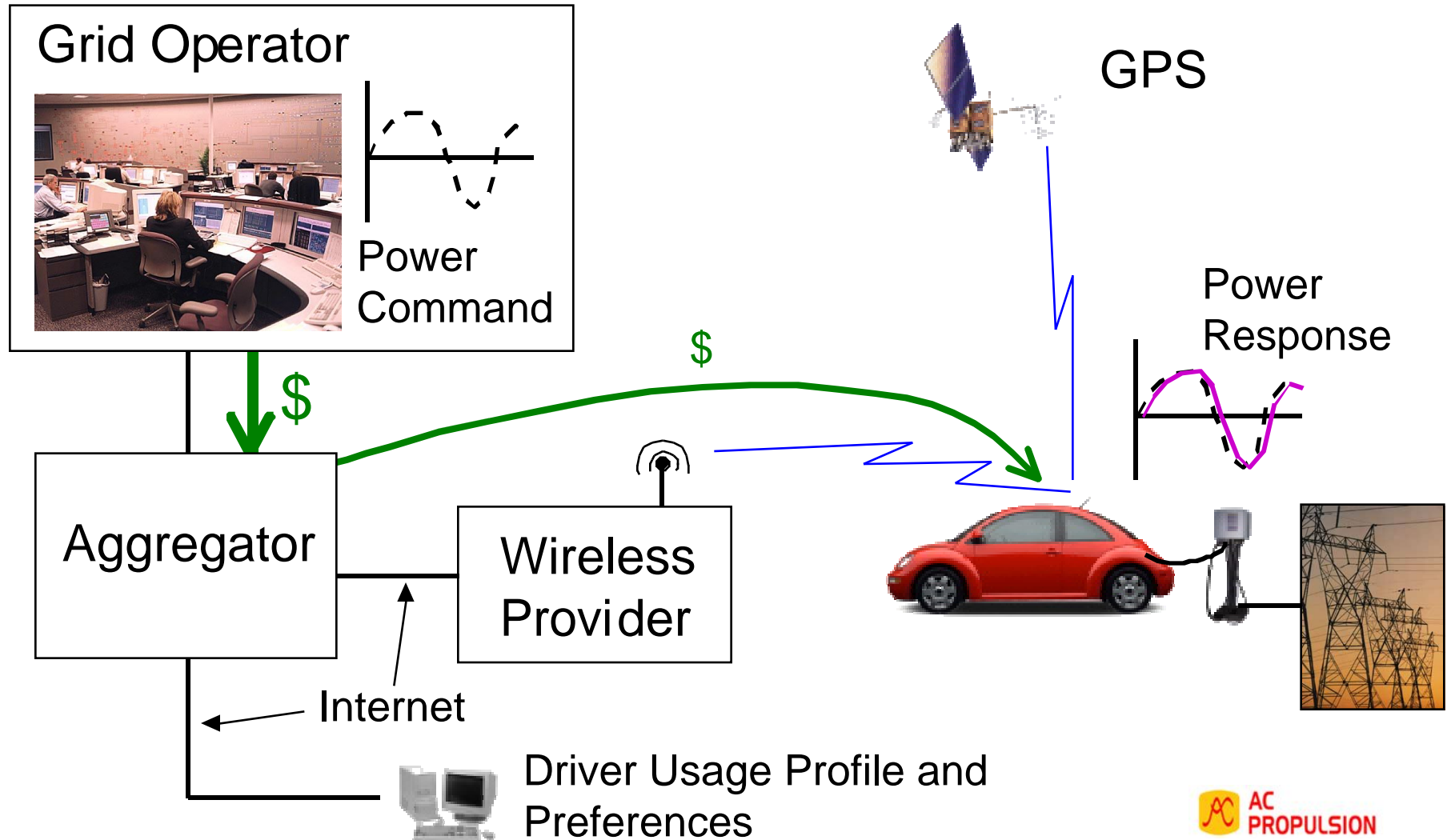
Electricity Powers Transportation Without Petroleum

V2G: An Evolving Concept

- 1995 Amory Lovins proposes grid power from FCEV s
- 1997 Kempton and Letendre paper on vehicle-to-grid, EVS14: Off-board fast chargers for grid support
- 2000 Nissan Patent “Household Power Supply Using EV”
- 2001 AC Propulsion first test bi-directional AC150 Gen 2, DaimlerChrysler - “We can use the energy unit in this car for homes or stationary power”, EPRI: “The Car of the Future May Help Power Your Home”
- 2002 General Motors - “The car or truck would ... also be a power source... that can provide transportation, power or heat”, AC Propulsion demo of grid regulation by EV
- 2003 AC Propulsion demo of grid-tied and stand-alone power from hybrid vehicle
- 2005 The Seattle Electric Vehicle to Grid Forum

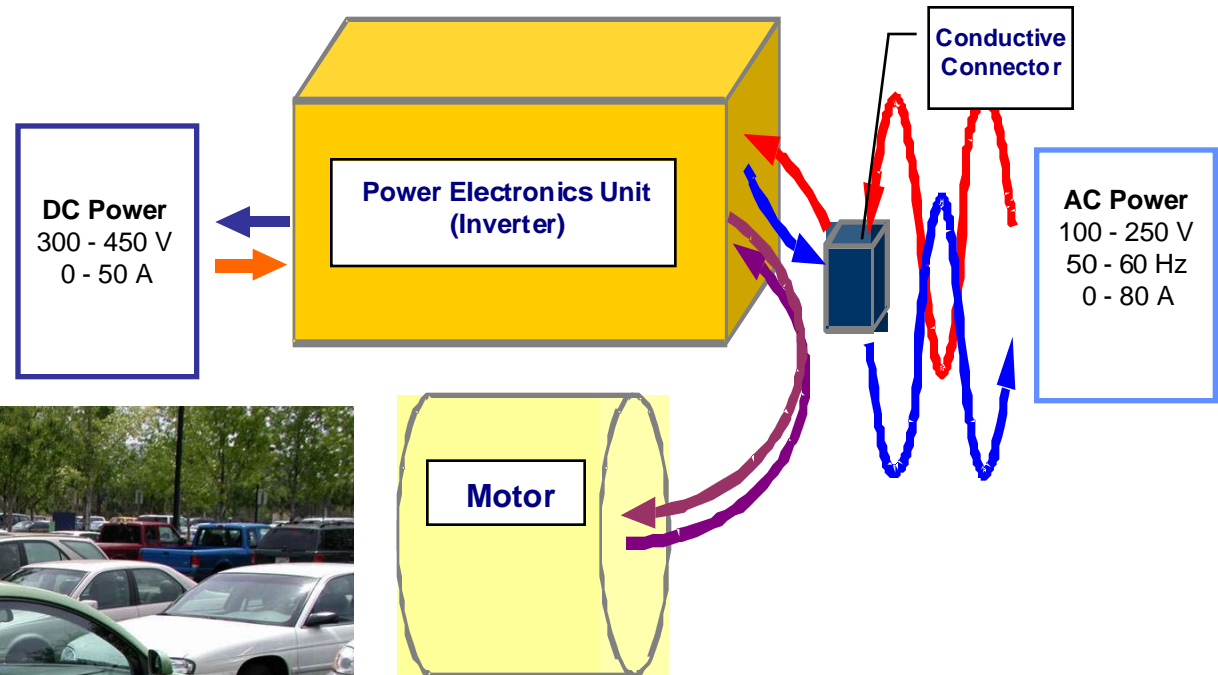
The Vehicle-to-Grid Concept - V2G

Connected vehicles serve as distributed energy resource (DER)



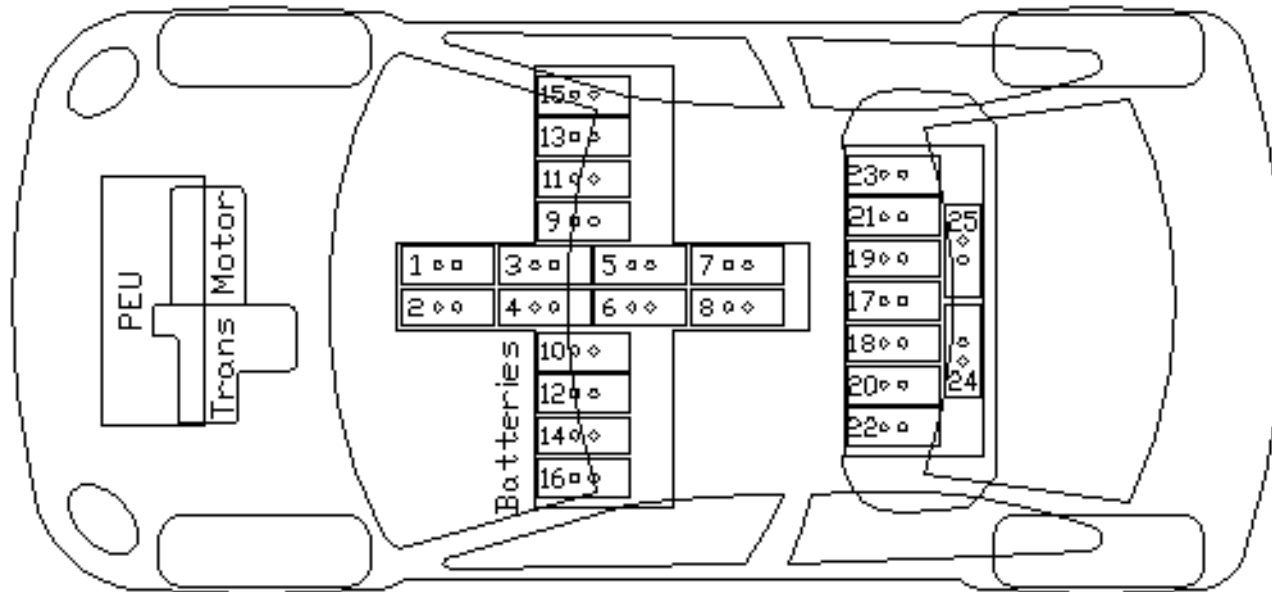
Key to V2G: Power Connection is Bi-Directional

Power can flow to or from vehicle



- Grid-tied
- Stand-alone

Battery Electric



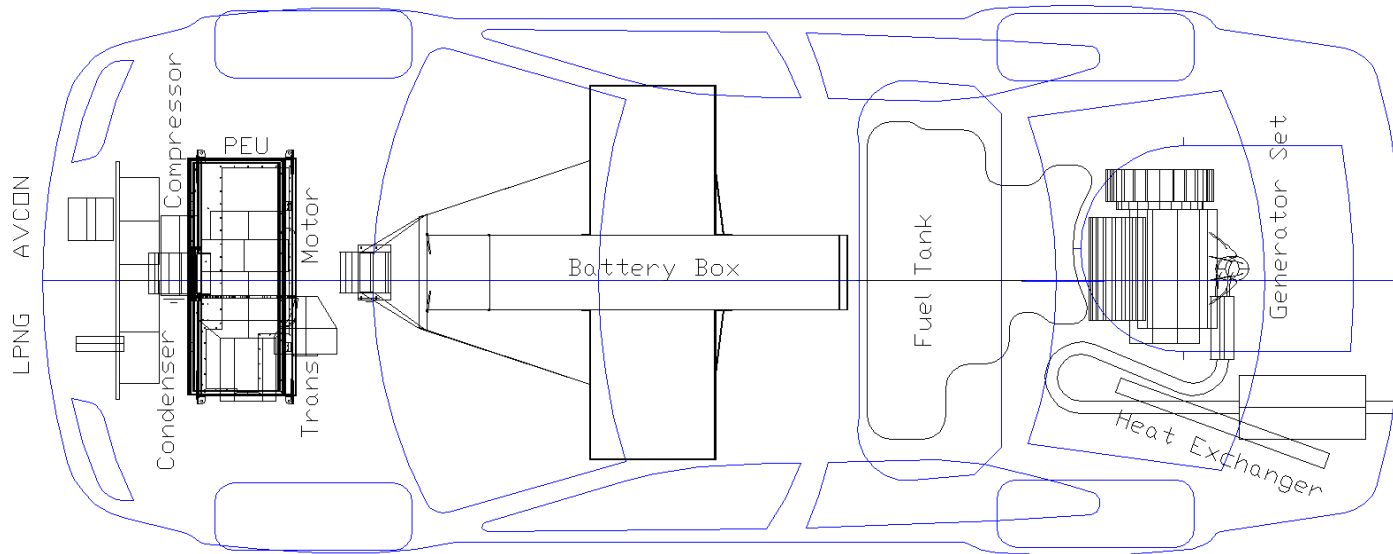
- Full function: 0-60 < 10 secs, > 80 mph
- Battery: 10 to 50 kWh, 300 to 1200 lbs
- Range: 50 to 300 miles
- Propulsion power: 70 to 150 kW
- Charging power: 5 to 20 kW

Battery Electric with Hybrid Generator



**RAV4 EV with range extending trailer
Tejon Pass (elev 4144 ft) December, 2001**

Plug-in Hybrid (Series Type)



- Full function: 0-60 < 10 secs, 80 mph
- Battery: 5 to 25 kWh, 150 to 600 lbs
- Range: 20 to 80 electric, >350 gas
- Propulsion power: 50 to 100 kW
- Charging power: 5 to 20 kW



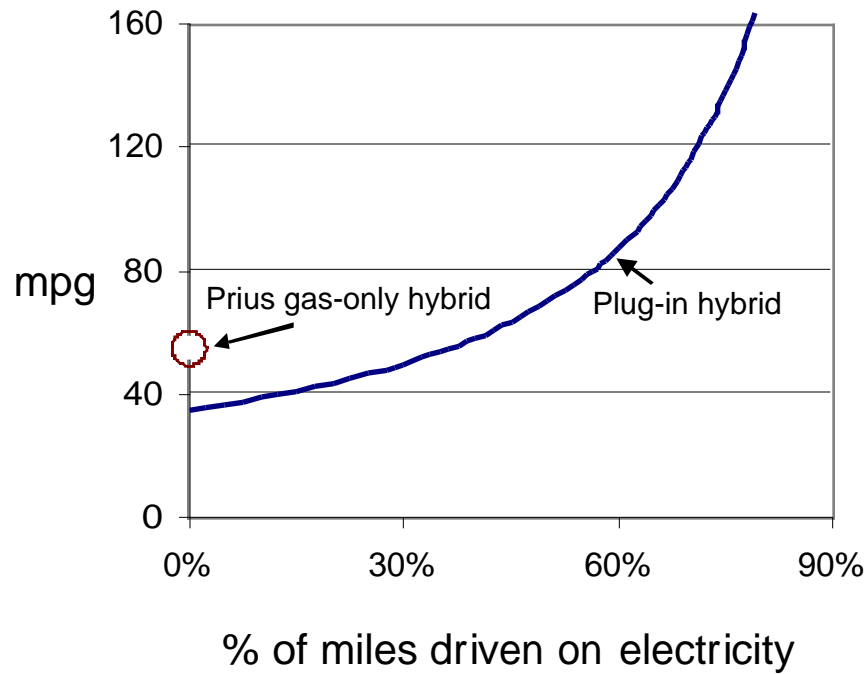
2002 Hybrid Conversion based on VW Jetta

Plug-in Hybrid vs Gas-only 2004 Prius



Engine	1.4 liter 35 kW	1.5 liter 56 kW
Generator	30 kW	20 kW (est)
Traction Motor	110 kW	50 kW
Transmission	Fixed ratio	Planetary
Battery	PbA 8 kWh 650 lb	NiMH 2 kWh 100 lb (est)
Charger	20 kW (V2G)	none
Charge port	conductive	none

Plug-In Hybrids Use Gas and Electricity



35 kW APU
mounts in
trunk



Plug-in Prius: 125 MPG



- 9 kWh battery
- 3 kW charger
- Control unit

Plug-in Prius demo by Energy CS
EVS-21, Monaco, April 2005

BEV vs PHEV: Function

BEV

- More electric range
- Pure electric propulsion
- Battery and charger typically larger, better suited for most V2G services

PHEV

- More total range
- Combined or pure electric propulsion
- Can generate bulk electricity from other fuel

BEV vs PHEV: Cost

BEV

- Single power system
- Larger battery
- Deep battery cycles

PHEV

- Dual power systems, more complexity
- Emissions control hardware and warranty
- Smaller battery
- Shallow or deep battery cycles

Market Factors

- Cost of ICE vs cost of battery
 - First cost
 - Operating cost
- Value of extended range to customer
- V2G optimality