A market study on Hybrid vehicles and the concept of V2G

Contents

Define EV Technology and Markets

Definition and Forecasts

- **What are electric vehicles?**

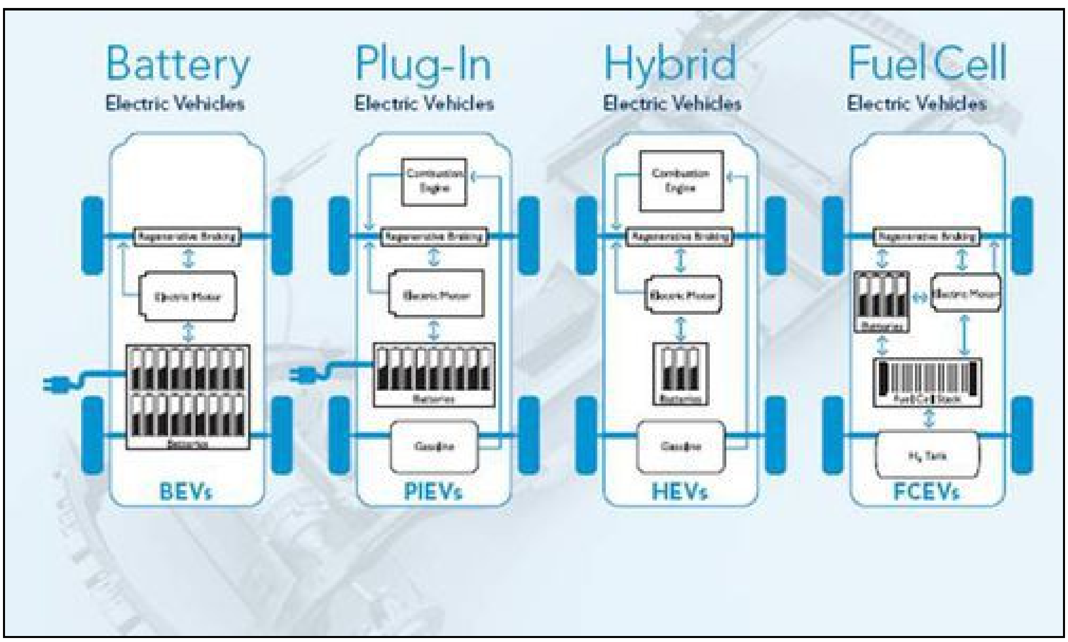
- An electric vehicle (EV) is a vehicle with one or more electric motors for propulsion. This is also referred to as an electric drive vehicle. The motion may be provided either by wheels or propellers driven by rotary motors, or in the case of tracked vehicles, by linear motors.

Unlike an internal combustion engine (ICE) that is tuned to specifically operate with a particular fuel such as gasoline, diesel or natural gas, an electric drive vehicle needs electricity, which comes from sources such as batteries or a generator. This flexibility allows the drive train of the vehicle to remain the same, while the energy source can be changed.

The electricity used to propel the vehicle may be provided in many different ways; it can come from any energy source, fossil fuels, nuclear power,and renewables (tidal power, solar, wind etc) and can either be supplied to the vehicle continuously as it is used or stored in the vehicle in some way, such as batteries, supercapacitors or fuel cells.

Electric vehicles can include electric cars, electric trains, electric airplanes, electric boats, and electric motorcycles and scooters even electric spacecraft. [1]

Below figure shows the architecture of the Vehicles along with the types.



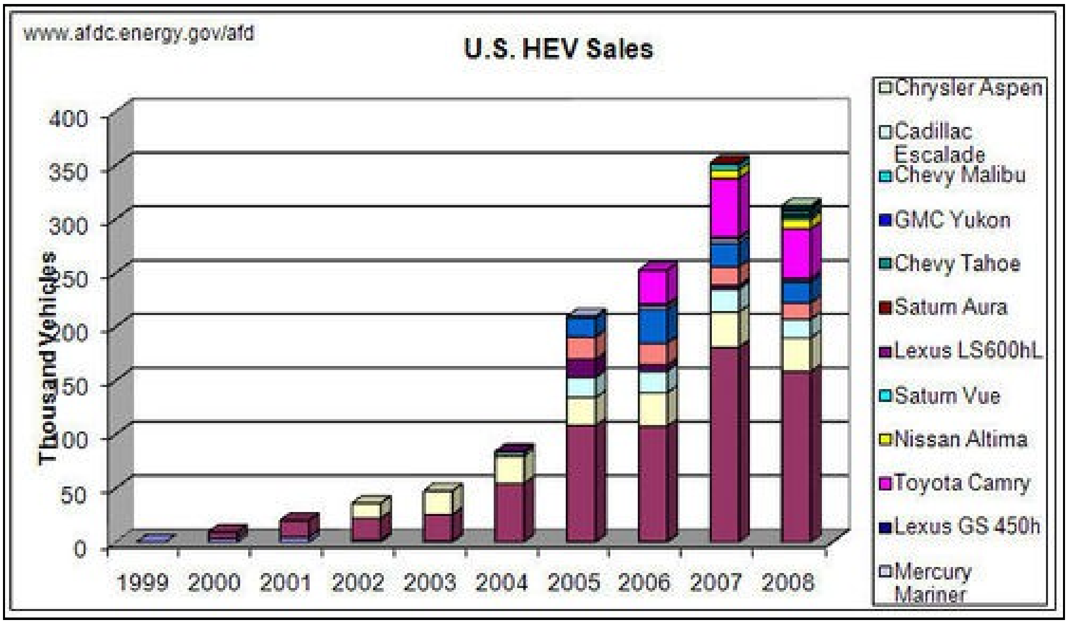
Types of EV

Plug-in Electric Vehicles

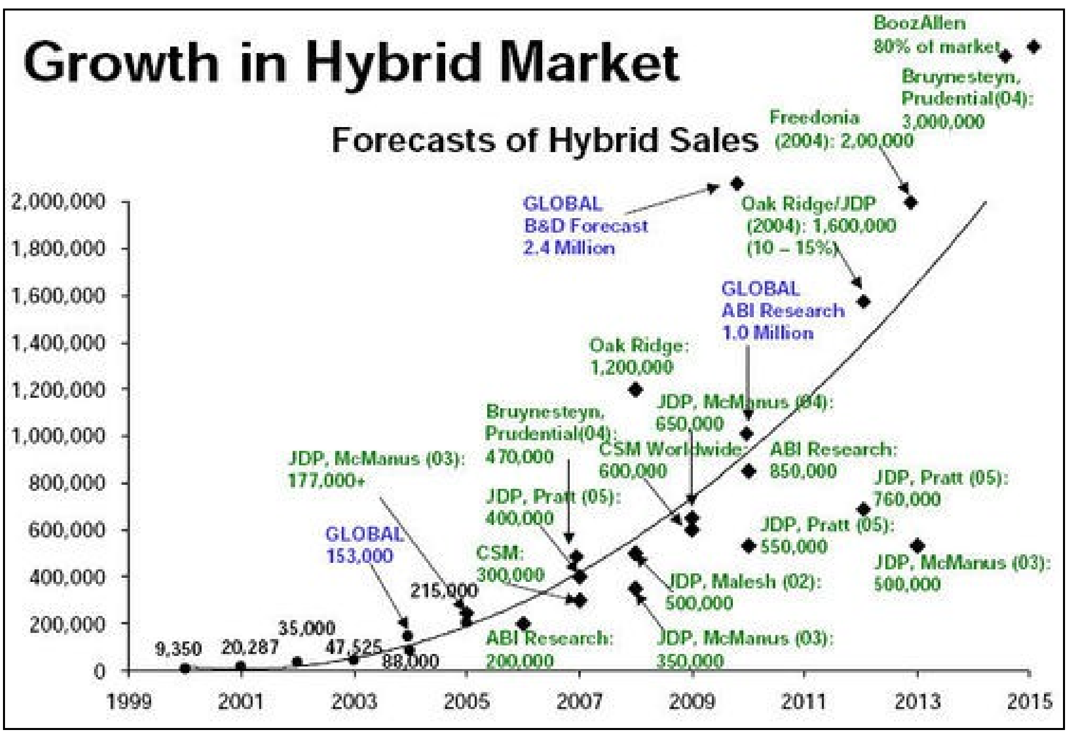
- What is a plug-in hybrid?

- PHEV, as it is called, is a normal hybrid vehicle, which has been modified to run off the electric grid. It retains all the functionality of a normal hybrid with higher than conventional mileage and lower emissions. Not all hybrids can be converted to a PHEV though. PHEV conversions can only be carried out full hybrids such as the Toyota Prius, the Ford Escape Hybrid, the Mercury Mariner Hybrid, and others. These vehicles are capable of running only on electric power directly from the factory.

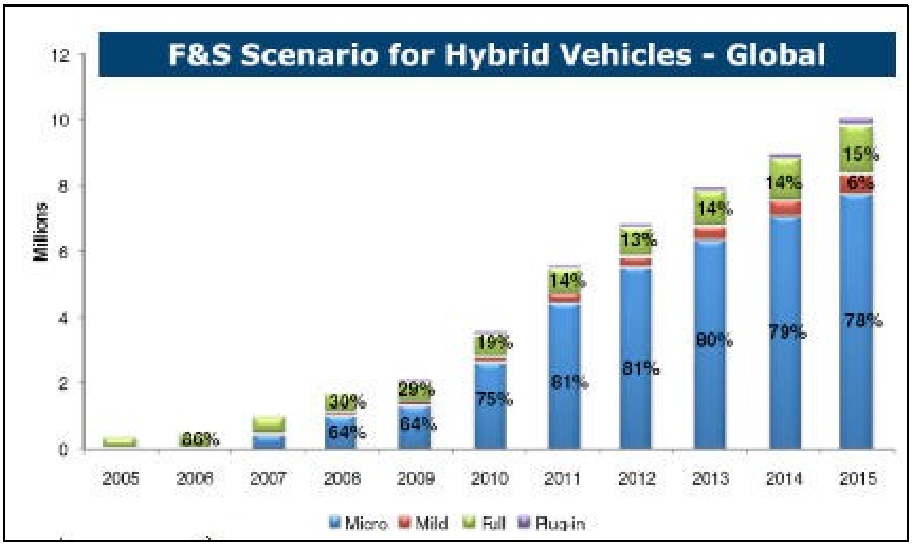
Below graph shows the historic sales of various Hybrid Electric Vehicles available in the market.



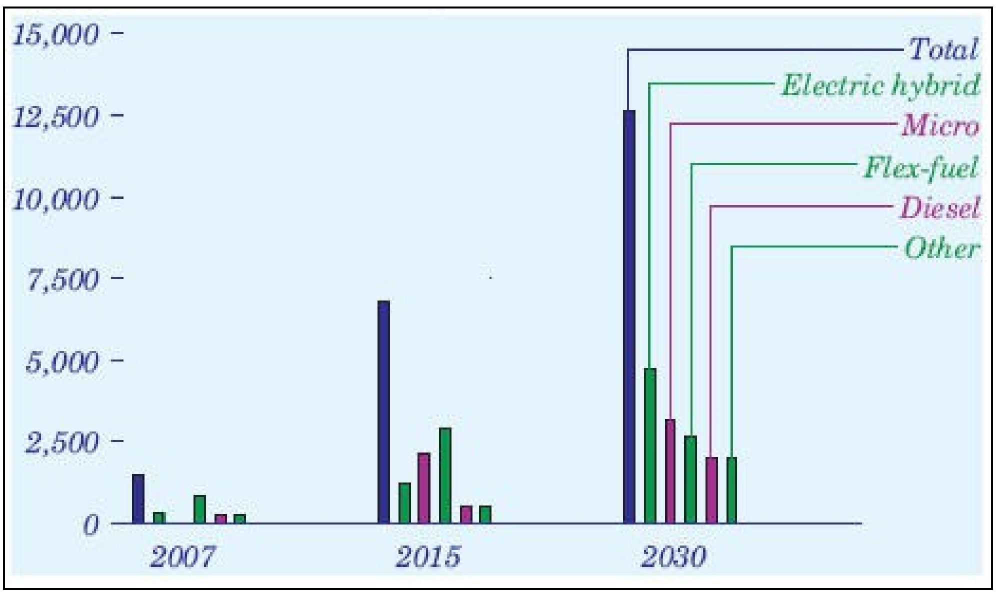
Historic Hybrid vehicle sales
This image shows the forecasts done by various research agencies on future sales of Hybrid Vehicles.



Source Hybridcars.com
Forecast of various form of plug-in hybrid Vehicles-Global by Frost and Sullivan

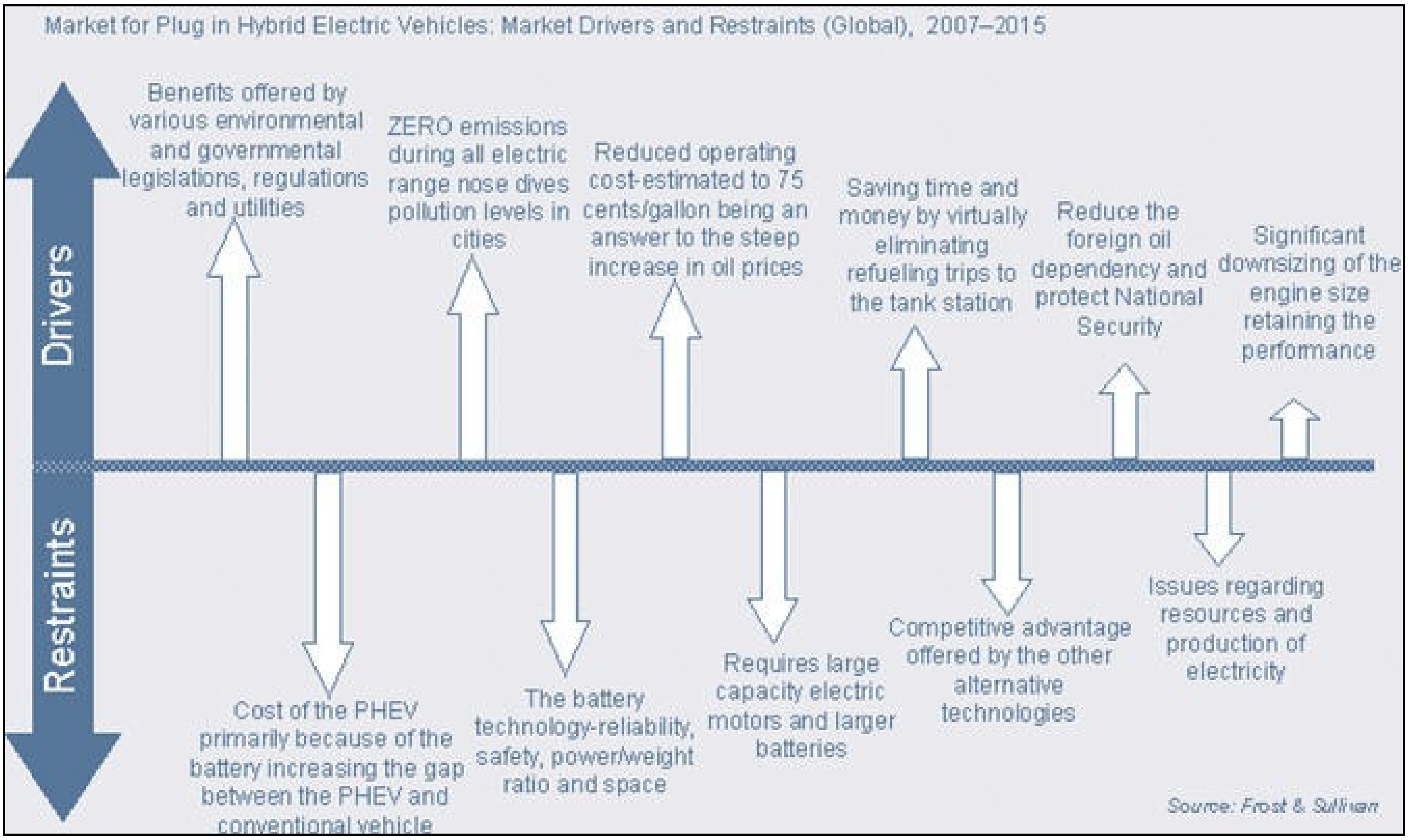


Source: Frost & Sullivan
The below graph shows the forecast of Sales of hybrid vehicles in USA.



Source:Annual Energy Outlook 2009 by U.S. Department of Energy

Restraints and Drivers for PHEV



Source: Frost & Sullivan

Legislative Background(for arizona)

Arizona Incentives and Laws (Updated June 2009)

State Incentives

- High Occupancy Vehicle (HOV) Lane Exemption
- Electric Vehicle (EV) Equipment Tax Credit
- Alternative Fuel Vehicle (AFV) Parking Incentive

State Laws and Regulations

- Low Emission Vehicle (LEV) Standards
- Biofuels Infrastructure Grants and Specifications
- Clean Fuel Contracts for Heavy-Duty Equipment
- Joint Use of Government Fueling Infrastructure
- Alternative Fuel Use and Acquisition Requirements
- Alternative Fuel and Alternative Fuel Vehicle (AFV) Tax Exemption
- Alternative Fuel Vehicle (AFV) Emissions Test Requirement
- Alternative Fuel Vehicle (AFV) Special License Plate
- Alternative Fuel Vehicle (AFV) License Tax
- Electric Vehicle (EV) Parking
- Alternative Fuel Vehicle (AFV) Dealers Information Dissemination Requirement
- Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) Device Fee
- Neighborhood Electric Vehicle (NEV) Access to Roadways
- School Bus Idle Reduction Pilot Program
- Idle Reduction Requirement - Maricopa County

Utilities/Private Incentives

There are currently no known utility or private incentives offered in Arizona.

Technologies for Energy Storage

- This chart shows the market share of various companies in US(2007).

Market share of battery companies in currently available hybrids cars in US

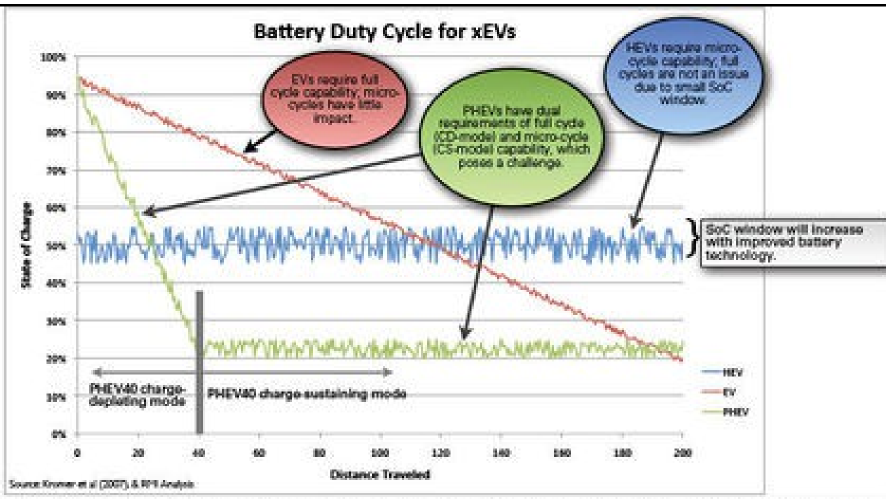
- The below chart shows the stage of commercialization and various parameters of battery performance for a given technology.

			USABC Goal Categories				
		Stage of Development	Power	Energy	Life	Safety	Low Cost
Chemistry	**Pb-Acid**	Mass Commercialization	Very limited power density	Extremely limited energy density.	Proven cycle and calendar life for conventional vehicles, but not adequate for xEV applications.	Proven record of safety. Environmental impact mitigated by extensive lead recycling infrastructure.	Very low cost.
	Ni-Cd	Mass Commercialization	Limited power density.	Very limited energy density.	Good cycle and calendar life.	Proven safety record in consumer electronics. Cadmium is toxic.	Relatively high c little room for re
	NiMH	Mass Commercialization	Limited power density.	Limited energy density.	Proven longevity for calendar and cycle life.	Proven history of safety.	Limited prospect reductions.
Li-Ion	**$LiCoO_2$/Graphite (LCO)**	Commercialization	Good power density.	Good energy density.	Cycle life is suitable for consumer electronics, but poor for automotive applications.	Low to moderate: thermal runaway problems would be disastrous in automotive applications.	High: cost of cob limiting factor fo reduction possibi
Li-Ion	**$Li(Ni_{0.85}Co_{0.1}Al_{0.05})O_2$/Graphite (NCA)**	Pilot	Good power density.	Good energy density.	Good cycle life and calendar life.	Moderate: nickel-based eletrodes are thermally unstable and degrade at high states of charge.	Moderate: limite reductions due t cobalt and nicke
Li-Ion	**$LiFePO_4$/Graphite (LFP)**	Pilot	Good power density.	Moderate energy density.	Good - can be operated at wide SoC window and still achieve good cycle life.	Moderate to good: stable cathode material does not release oxygen, but graphite anode still reactive with electrolyte.	Low: one of the expensive Li-Ion chemistries due based cathode.
Li-Ion	**$Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$ / Graphite (NCM)**	Pilot	Moderate power density.	Moderate to good energy density.	Poor cycle life.	Moderate: nickel-based eletrodes are thermally unstable and degrade at high states of charge.	Moderate: limite reductions due t cobalt and nicke
Li-Ion	**$LiMn_2O_4$/Graphite (LMS)**	Developmental	Moderate power density.	Moderate energy density.	Moderate to excellent: potential for above-average cycle life, calendar life may have issues.	Good: manganese-based eletrode material is potentially safe.	Moderate: low c but cost per kWh due to limited en density.
Li-Ion	**$LiMn_2O_4/Li_4Ti_5O_{12}$ (LTO)**	Developmental	Moderate power density.	Moderate energy density, mitigated due to large SoC operating window.	Good to excellent cycle life.	Very stable cathode/anode combination that promises good to excellent safety.	High: potentially due to use of tit
Li-Ion	**$LiMn_{1.5}Ni_{0.5}O_4$ / $Li_4Ti_5O_{12}$ (MNS)**	Research	Good power density.	Moderate energy density.	Unknown.	Excellent.	Moderate.
Li-Ion	**$Li_{1.2}Mn_{0.6}Ni_{0.2}O_2$ / Graphite (MN)**	Research	Excellent power density.	Excellent energy density.	Unknown.	Excellent.	Moderate.
	Zinc-Air	Commercialization	Limited power density.	High energy density.	Long life for mechanically rechargeable type. Life unknown for electrically rechargeable type.	Very safe in storage, use, and disposal.	Low cost (driven zinc).
	NaNiCl (ZEBRA)	Pilot	Limited power density.	High energy density.	Low cycle life.	Very safe components, safe in operation and disposal.	Moderate cost, t potentially high use of nickel.

Source: Axsen et al (2008), Nelson et al (2007), Kromer et al (2007), Kalhammer et al (2007), & RMI Analysis

Comparision of current and future battery technologies

- This graph shows battery requirements for various technologies.



Vehicle Type	CD-Mode Range	Capacity (kWh)	Cost (@100k/year)	Utility Factor	Full Cycles Req'd	Micro Cycles Req'd	Cost / Full Cycle	Cost / Micro Cycle	Total Lifetime kWh	Lifetime Cost/kWh
HEV	0	1.5	$900	0%	0	300,000	-	$0.0030	45,000	$0.0200
PHEV-10	10	4	$1700	18%	2700	246,000	$0.1133	$0.0057	47,700	$0.0356
PHEV-20	20	6	$2250	31%	2325	207,000	$0.3000	$0.0075	45,000	$0.0500
PHEV-30	30	8	$2700	42%	2100	174,000	$0.5400	$0.0090	42,900	$0.0629
PHEV-40	40	12	$3400	51%	1913	147,000	$0.9067	$0.0113	45,000	$0.0756
PHEV-60	60	16.5	$4500	63%	1575	111,000	$1.8000	$0.0150	42,638	$0.1055
BEV-200	200	48	$12,000	100%	750	0	$16.0000	-	36,000	$0.3333

* Assumes 150,000-mile vehicle lifetime, 0.15 kWh micro-cycle magnitude. Based on Kromer et al. USABC battery goals, & RMI analysis.

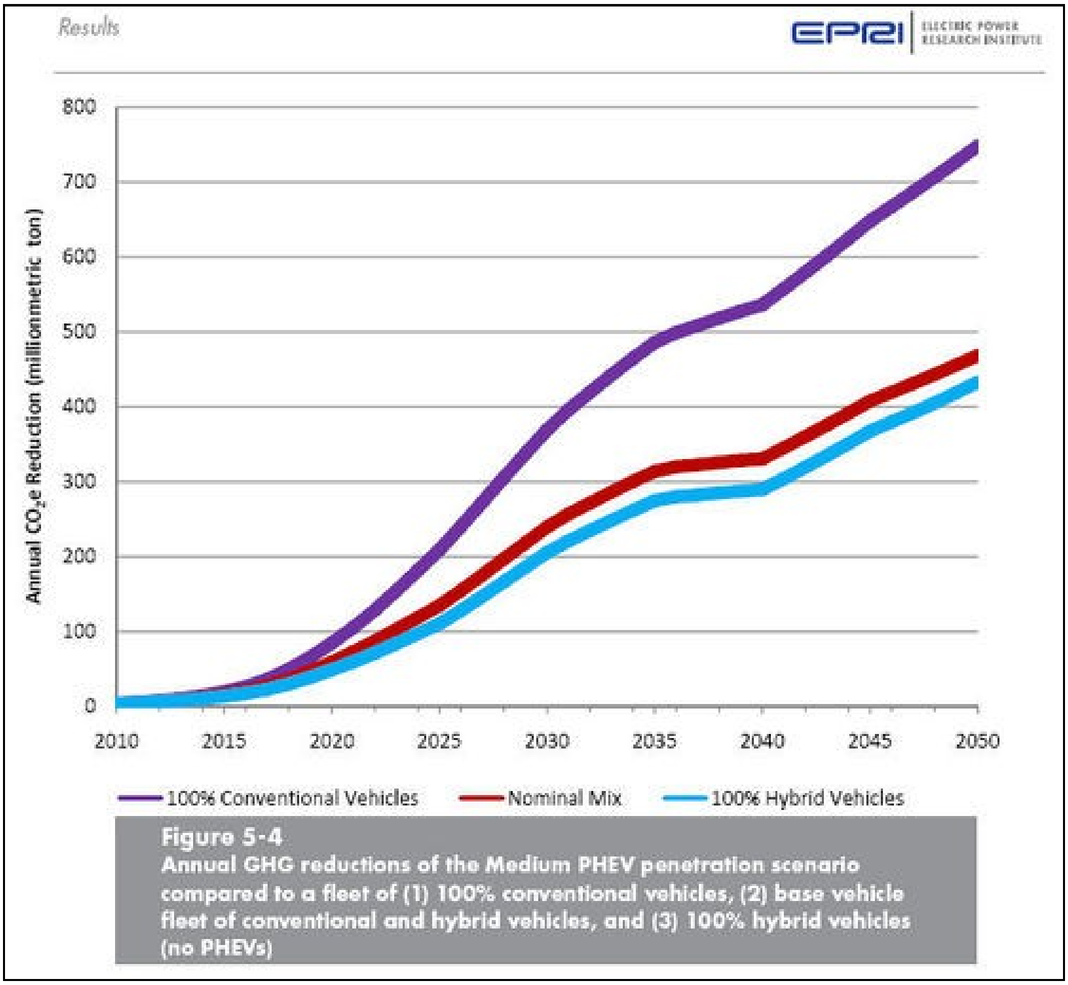
Charging Cycle Requitements for different type of EV's

Environmental Impact

This table shows how use of Electric vehicles can help reduce GHG emissions.

Vehicle type	Vehicle CO2 emissions (g/mi)	Upstream CO2 equivalent emissions (g/mi)	Total CO2 emissions (g/mi)	Lifetime CO2 equivalent emissions (ton)	Lifetime CO2 equivalent emissions reduced from 2002 baseline (ton)	Percent reduction from Conventional Gasoline Vehicle
Conventional vehicles	346.7	102.7	449	99.9	0.0	0%
Compressed natural gas (CNG)	284.8	92.9	378	83.9	15.9	16%
Liquid petroleum gas (LPG)	313.9	50.4	364	80.9	18.9	19%
HEV20	89.0	82.0	171	38.1	61.8	62%
Ethanol (E85)	356.9	-12.7	344	76.5	23.4	23%
Electric	0	150	150	33.4	66.5	67%

Emission reduction Possible by use of Ev's
Forecast of emission reduction by use of Various scenarios in America by EPRI



Emission reduction scenario in US by Penetration of hybrid car technology

Define Vehicle to Grid

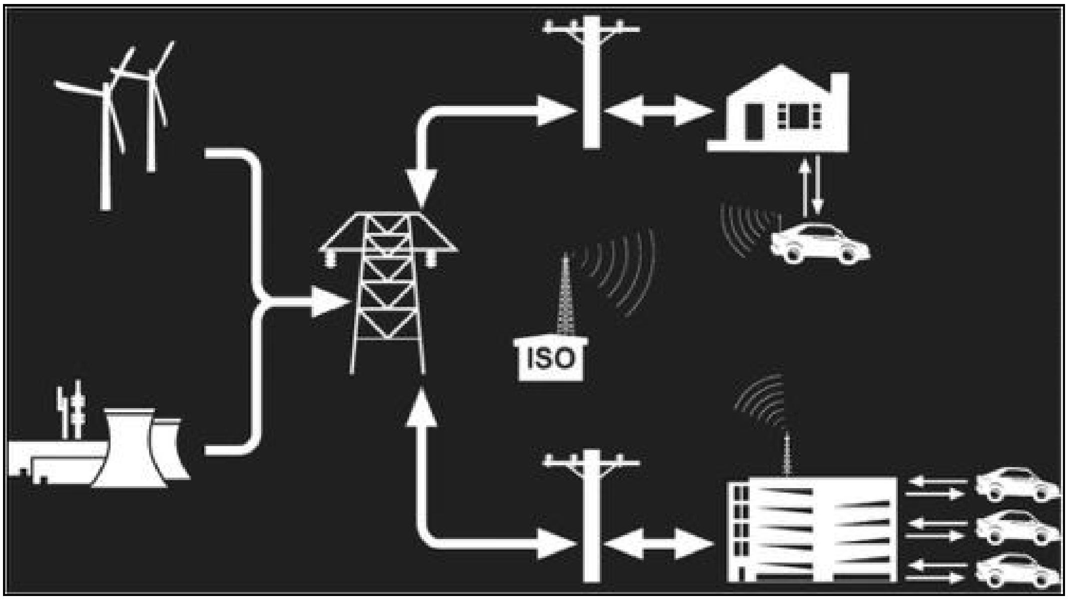
- **The Vehicle-to-Grid concept**

The concept of ?Vehicle-to-Grid? (V2G) was first proposed in 1997 by professor Willet Kempton of the University of Delaware in his article ?Electric vehicles as a new power source for electric utilities?

- **What is V2G?**

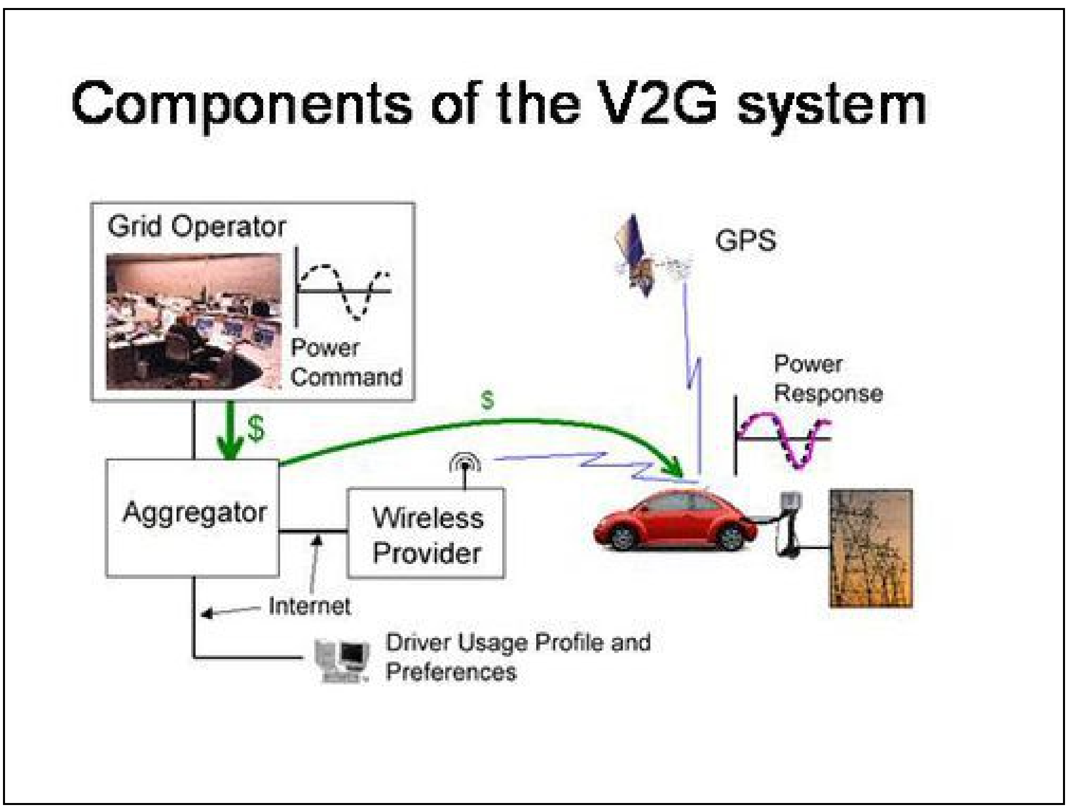
(PH)EVs have a battery pack (energy storage device) and a charger. The charger can be bidirectional; able to deliver power back to the grid from the vehicle?s battery as well as charge the battery. Typically, the battery recharge time is only a few hours. Since most vehicles are generally in use just a couple of hours per day, there is a flexibility to the timing and power profile of how and when vehicles are recharged, or even discharged into the grid. Kempton?s concept of V2G is based on such vehicles with remotely controlled, bidirectional chargers providing services to the electric power grid. The services that these vehicles provide to the grid have a value that may result in payments back to vehicle drivers, resulting in lower vehicle operating costs.

- **Working Model of V2G Process(Arrow shows direction of power flow)**



Working of V2G technology

- **Components of a V2G system**



Possible model to Introduce V2G technology

- **Aggregators**

In order to make V2G work properly, service providers (aggregators) will be required to organise MW-size ?blocks? of regulation/reserve/peak power. These service providers need to be able to communicate with the vehicles to obtain vehicle location, battery state-of-charge, owner preferences, and to transmit ?charge? or ?dispatch? signals.

- **Smart meters**

Metering of the V2G contribution to the grid of individual vehicles can be done with residential ?smart? meters, which are widely commercially available. Both in the US and in the EU, taskforces/working groups are working on standards for smart meters (US: UtilityAMI/OpenHAN, EU: NTA 8130).

Another option is to use an on-board metering device; this seems to make more sense in the case that the vehicle is controlled by an aggregator.

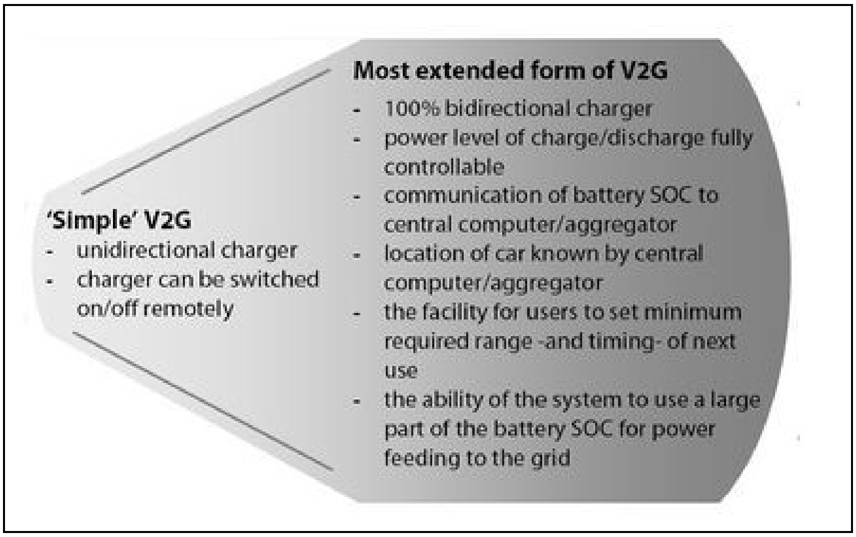
- **Communication**

Several ?smart grid? companies in the US are active in providing communication solutions between V2G-vehicles and TSOs/aggregators; examples are V2Green and GridPoint.

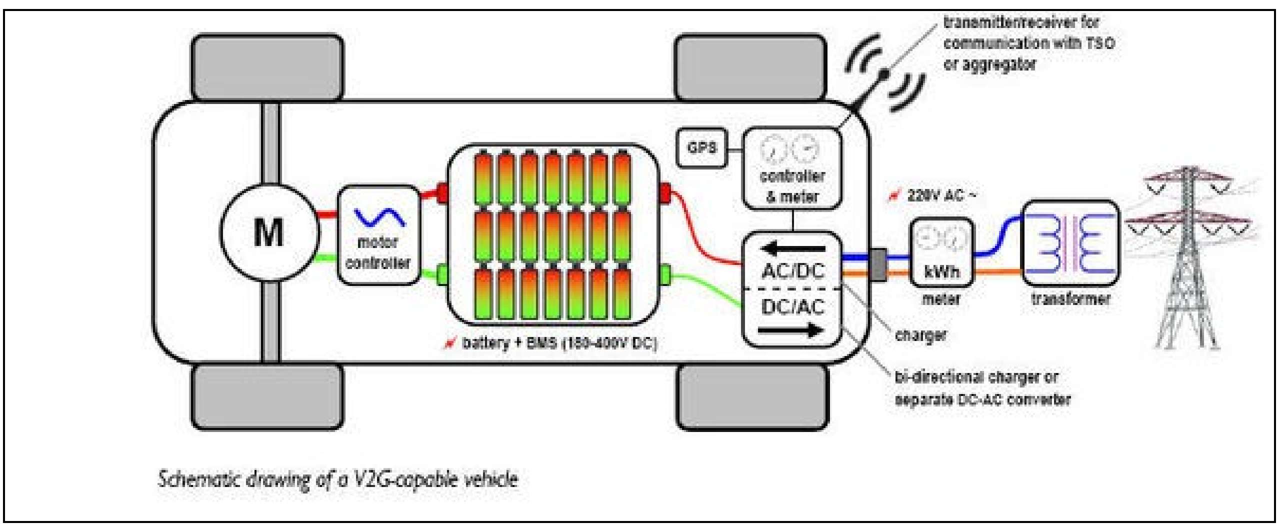
- **Standards for charge/discharge communication**

In the US, The National Electric Infrastructure Working Council (IWC, organised by EPRI) is working with the automotive industry to define a communications standard, enabling EVs to communicate to their charging infrastructure. The IWC is working closely with the SAE J1772 (EV charging standard) committee.[2]

- **Options for application of V2G.**



- **V2G capable Vehicle diagram**



Schematic drawing of a V2G-capable vehicle

V2G capable Vehicle Diagram

- **V2G-relevant vehicle components**

Battery

PHEVs have advanced batteries with a storage capacity of 4 to 15kWh, giving the vehicle an electric-only range of 15-80km. EVs generally have 15 to 50kWh on board, for a range of 80-300km. (PH)EV batteries should be able to provide a power of at least 30kW, to ensure convenient acceleration. The DC voltage of PH(EV) batteries is generally between 180V and 400V DC.

Battery management system (BMS)

Since individual battery cells have a voltage ranging from 1.2V to 3.6V, (PH)EV batteries are built from ±hundred to several thousands of battery cells. Such a multi-cell, high-energy battery pack requires complicated electronics and software to manage voltage, current levels and temperatures for each individual (module of) cells. This system is called the battery management system (BMS). The BMS also keeps track of the state-of-charge (SOC) of the battery, and controls the maximum power level of the charger and the maximum regenerative breaking level.

Battery charger (AC-DC) & inverter (DC-AC)

(PH)EV chargers have an output voltage of 180-400 Volt DC. If they are rated for a standard 220V AC socket, their maximum (dis-)charge power in Europe is generally ±3.5kW. In the US, the residential socket output is 110V, and maximum power output limited to ±1.5kW. If a two-phase AC outlet is used, a much higher charge power can be drawn (15-20kW is the current state-of-the art).

In many European countries, there is a 2-phase 380V connection inherently present in every home, since the electricity system brings a 3-phase cable (3 x 220V) to every household. A 380V socket can then easily be added to a residential or small business connection. Most V2G research goes from the assumption that future (PH)EVs will have a charger with a (dis-)charge power level of 10-20kW, and that there will thus be dedicated EV charging connections installed in the house of (PH)EV owners.

The battery management system controls the maximum charge level of the charger, which is usually connected to the BMS via a CAN-interface. In order to let the battery deliver power back to the grid, either the charger needs to be bi-directional, or a separate DC-AC inverter is required.

Controller, GPS & electricity meter

To regulate the power taken from or fed into the grid by the vehicle, a remotely controlled regulation device is required. The signal that controls the regulation device can be provided in the following ways:

1. via the cellular phone network
2. via a radio signal
3. via the ?Internet? (last part WLAN connection)
4. via a ?smart meter? network (last part wirelessly, first part Internet or cellular phone network)
5. via the power grid (TSO signals)

Ideally, a GPS device keeps track of where the vehicle is and an on-board electricity meter measures in- and outflow of electricity.

Outside vehicle: (Smart) meter

In a less advanced V2G scenario, it is not the on-board meter that measures electricity consumed and generated by the vehicle, but a (smart) residential electricity meter.