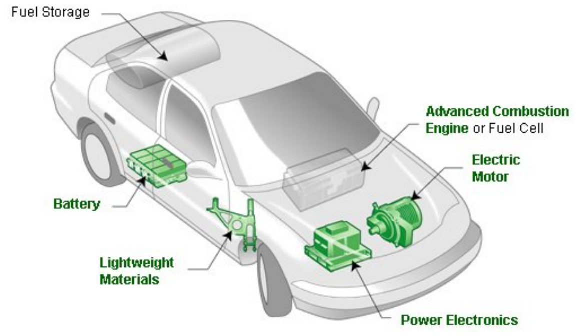
Electric Vehicles *Fact Sheet*

Nicole Catino
Fall 2012
LAFAYETTE COLLEGE

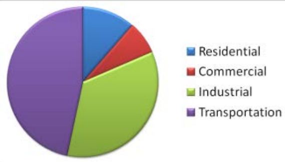
Advantages
- Reduces carbon emissions
- Decreases dependence on imported oil
- Fewer parts; easier to maintain
- Regenerative braking reduces need for fossil fuel (HEV, PHEV)
- Advances power electronics
- Reduces noise pollution

Challenges
- Limited driving range
- Long charging time
- High cost of battery
- Immature infrastructure



An example of a hybrid electric vehicle with parts labeled

Abbreviations
EV- Electric Vehicle
HEV- Hybrid Electric Vehicle
PHEV- Plug-in Hybrid Electric Vehicle
ZEV- Zero Emission Vehicle
ICE- Internal Combustion Engine
CV- Conventional Vehicle



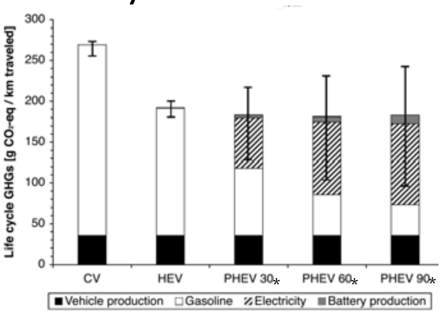
2011 Primary Energy Consumption by End-Use Sector

	CV	HEV	PHEV	EV
Propulsion System	ICE	ICE + Electric Motor	ICE + Electric Motor	Electric Motor
Fuel	Liquid fuel	Liquid fuel	Liquid fuel, Electricity	Electricity
Battery	Lead Acid	NiMH	Li-ion	Li-ion

Batteries
One of the challenges with EVs is that today's battery technology (the energy source in EVs) has a low energy density compared to liquid fuels such as gasoline or diesel. Therefore, the batteries in EVs are rather large and contribute to the high capital cost.

Newer lithium-ion (**Li-ion**) batteries have a higher energy density than previous batteries such as nickel metal hydride (**NiMH**) or **lead acid**, but is still much lower than liquid fuel.

Life Cycle GHG Emissions



*PHEVs with all-electric ranges of 30, 60, or 90km

Pollution Reduction
One of the attractive characteristics of the EV is reduced pollution emissions. When looking at the tailpipe of an EV this is certainly true, but if the electricity used for propulsion is coming from burning of fossil fuels, the pollution source is simply being relocated along the production line.

Well-to-wheel (**WTW**) analysis incorporates efficiency on a holistic level– from fuel extraction in the wells to the energy needed to move the wheels, and every step along the way. WTW can be broken up in two sections for a closer analysis– well-to-tank (**WTT**) and tank-to-well (**TTW**). These can then be compared across vehicles using the **GREET** model, which stands for greenhouse gases, regulated emissions, and energy use in transportation.

Infrastructure
A comprehensive foundation is necessary for EVs to become more widespread. This includes, but is not limited to: charging stations, standardization of equipment and safety issues, reliable support, and increased renewable energy generation.

Energy Consumption, Efficiency, and Emissions for Passenger Cars Using GREET

	ICE	PHEV	EV
Total Energy (W h)	257,551	526,261	1,632,131
WTT efficicnecy	79.5%	66.5%	38.0%
TTW efficiency	21.9%	23%	48.51%
WTW efficiency	17.41%	15.29%	18.43%
CO_2 (g/million BTU)	17,495	57,024	219,704
CH_4 (g/million BTU)	109.120	145.658	296.031
N_2O (g/milion BTU)	1.152	1.535	3.111
VOC: Total (g/million BTU)	27.077	25.630	19.679
CO: Total (g/million BTU)	15.074	23.553	58.448
NO_x: Total (g/million BTU)	50.052	87.100	239.571

Fuel Economy Comparisons Across Vehicles

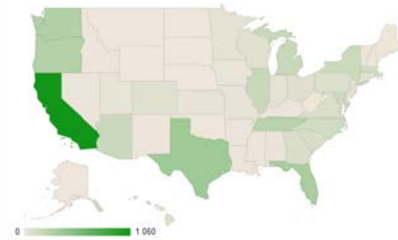
	ICE 2012 Honda Accord	HEV 2012 Toyota Prius	PHEV Chevrolet Volt	EV 2012 Nissan Leaf
Manufacturer's Suggested Retail Price (MSRP)	$21,480 - $31,930	$24,000 - $29,805	$39,145	$35,200
Miles per Gallon (MPG)	27	50	37	-
Miles per Gallon of Gasoline Equivalent	-	-	98	99
Miles on a Tank/Charge	450	536	380	73
Time to Charge Battery	-	-	4 hrs @ 240 V	7 hrs @ 240 V
Annual Fuel Cost	$1,950*	$1,050*	$950**	$600***

*Based on 45% highway, 55% city driving, 15,000 annual miles and current fuel prices.

**Based on 15,000 miles annual driving and an electricity cost of $0.12/kWh and gasoline prices of $3.99 per gallon for premium and $3.72 per gallon for regular

***Values rounded to nearest $50. Based on 15,000 miles annual driving and an electricity cost of $0.12/kWh

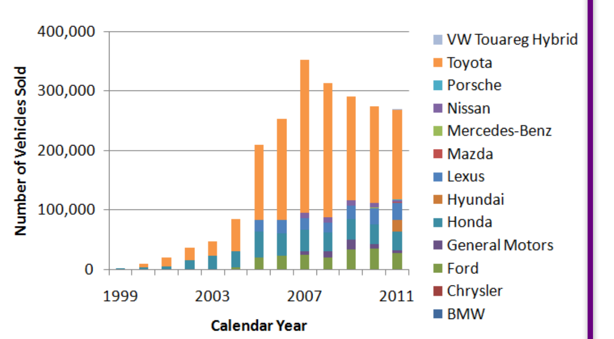
Electric Charging Station Locations by State



Timeline
- 1834: The first EV is invented
- 1912: 34,000 EVs are registered and they outnumber gas-powered vehicles 2-to-1
- 1920s: EVs disappear and ICE vehicles become predominant
- 1973: Arab oil embargo increases demands for alternative energy sources
- 1976: Congress enacts the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976
- 1990: California Air Resources Board (CARB) mandates that 2% of vehicles should be ZEV by 1998, 5% by 2001, and 10% by 2003. (Later relaxed because of infeasibility)
- 1993: The Partnership for Next Generation Vehicles (PNGV) is established between federal laboratories and automotive industries
- 2008: Tesla motors produces the Tesla Roadster, which is the first vehicle to use a Lithium-ion battery and the first BEV to travel more than 200 miles on a single charge
- 2009: The Corporate Average Fuel Economy standard (CAFÉ) sets the average fuel economy to be 35 MPG by 2020
- 2009: The US President provides $2.4 billion for PHEV development and establishes a goal of having 1 million PHEV on the road by 2015

1834 — 1900 — 2000

HEV Sales by Manufacturer



References

Nicole Catino
Fall 2012
LAFAYETTE COLLEGE

For more:

U.S. DOE Alternative Fuels Data Center
http://www.afdc.energy.gov/

U.S. DOE Vehicle Technologies Program
http://www1.eere.energy.gov/vehiclesandfuels/index.html

Hybrid Electric Vehicle (img)

DOE Vehicle Technologies Program-- Hybrid Electric Vehicles (HEV)
http://www1.eere.energy.gov/vehiclesandfuels/technologies/systems/hybrid_electric_vehicles.html

For more:

http://www.fueleconomy.gov/feg/hybridAnimation/hybrid/hybridoverview.html

EIA Monthly Energy Review
http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_3.pdf

Comparison of ICE, HEV, PHEV, EV

Center for Automotive Research (CAR) Green and Connected
http://www.cargroup.org/assets/files/green.pdf

Batteries

Mi, Chris, M. Abul Masrur, and David Wenzhong Gao. *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*. Chichester: John Wiley & Sons, 2011. Print.

Life Cycle GHG Emissions

Samaras, C. and Meisterling, K. (2008) "Life Cycle Assessment of Greenhouse Gas Emissions from Plug-in Hybrid Vehicles: Implications for Policy"
http://pubs.acs.org/doi/pdfplus/10.1021/es702178s

Pollution Reduction

Husain, Iqbal. *Electrical and Hybrid Vehicles: Design Fundamentals*. 2nd ed. Boca Raton: CRC, 2011.

Infrastructure

Mitchell, William J., Christopher E. Borroni-Bird, and Lawrence D.Burns. *Reinventing the Automobile: Personal Urban Mobility for the 21st Century*. Cambridge: MIT P, 2010.

Energy Consumption, Efficiency, and Emissions for Passenger Cars Using GREET

Husain, Iqbal. *Electrical and Hybrid Vehicles: Design Fundamentals*. 2nd ed. Boca Raton: CRC, 2011.

For more:
GREET Model
http://greet.es.anl.gov/

Fuel Economy Comparisons Across Vehicles

DOE FuelEconomy.gov
http://www.fueleconomy.gov/

For more:
HEV: http://www.fueleconomy.gov/feg/hybrids.jsp
PHEV: http://www.fueleconomy.gov/feg/phevsbs.shtml
EV: http://www.fueleconomy.gov/feg/evsbs.shtml

Electric Charging Station Locations by State

DOE Alternative Fuels Data Center (AFDC) Electric Charging Station Locations by State
http://www.afdc.energy.gov/data/tab/all/data_set/10366

Timeline

Husain, Iqbal. *Electrical and Hybrid Vehicles: Design Fundamentals*. 2nd ed. Boca Raton: CRC, 2011.

Mi, Chris, M. Abul Masrur, and David Wenzhong Gao. *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*. Chichester: John Wiley & Sons, 2011.

HEV Sales by Manufacturer

Oak Ridge National Lab (ORNL) Transportation Energy Data Book, section 6-8
http://cta.ornl.gov/data/chapter6.shtml

DOE Alternative Fuels Data Center (AFDC) U.S. HEV Sales by Model
http://www.afdc.energy.gov/data/tab/vehicles/data_set/10301