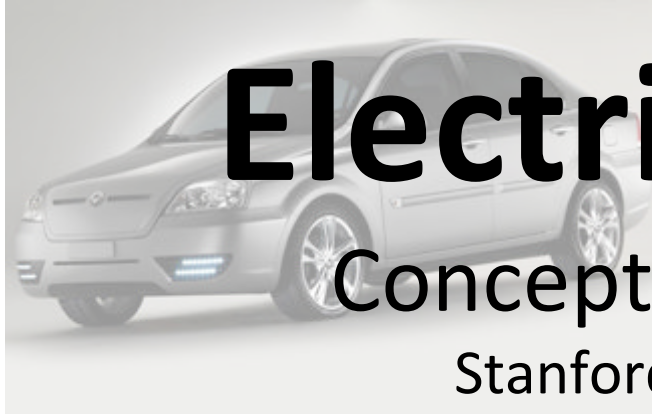




# Electrified Vehicles

Concepts, Specifics, Examples

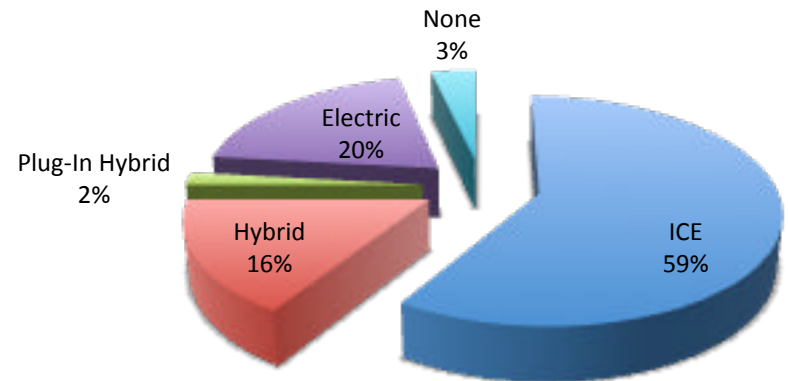
Stanford University – January 2011



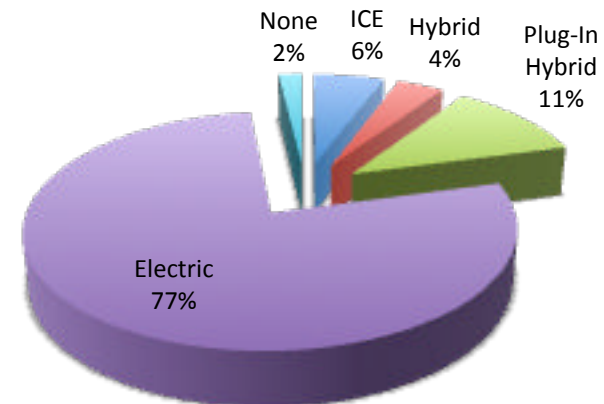
# How Do You Feel About Electric Vehicles?

A spontaneous poll in class: ME302 / CS523 - Jan 5, 2011 – total of 54 students

1. What powertrain concept will you buy as your next car?

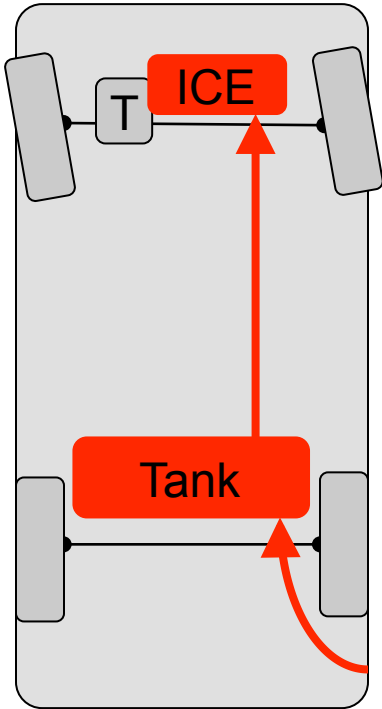


2. Which car would you choose for a test drive next weekend?



# Concepts of Electrified Vehicles

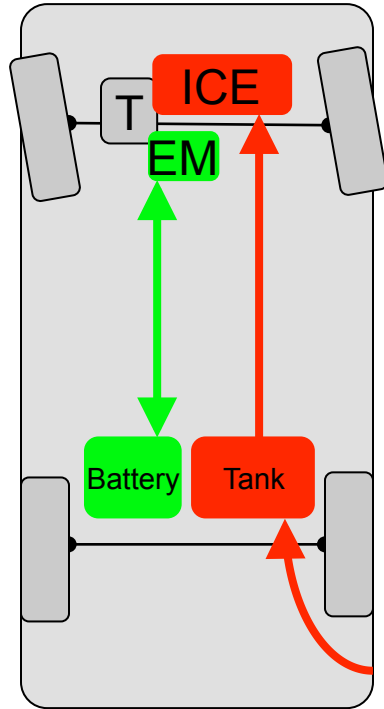
## Conventional



Non-Electric Vehicle

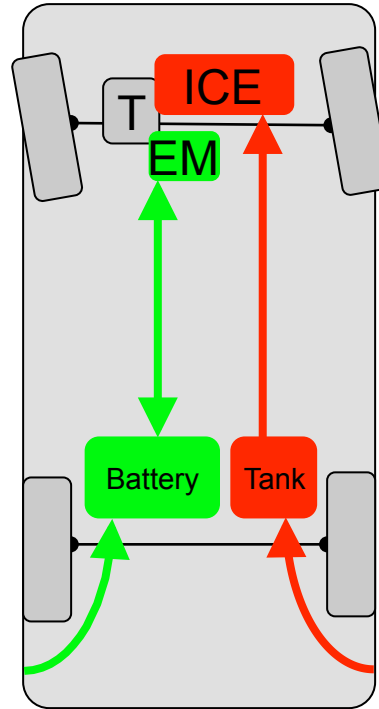
Large range  
Low cost  
Convenient

## Electrified



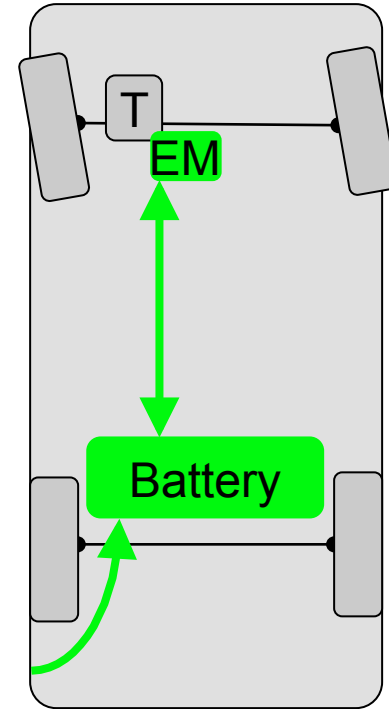
Hybrid Electric Vehicle (HEV)

Large range  
Optimized efficiency  
Partially "zero emission"



Plug-In Hybrid Electric Vehicle (PHEV)

Large range  
Optimized efficiency  
Extended "zero emission"

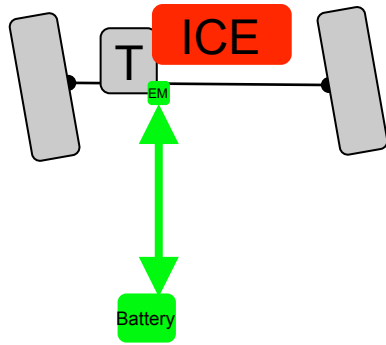


Battery Electric Vehicle (BEV)

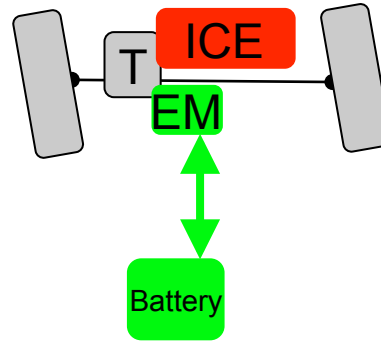
Full "Zero emission"  
"No petroleum"  
Simplified design

# Concepts of Hybrid Electric Vehicles

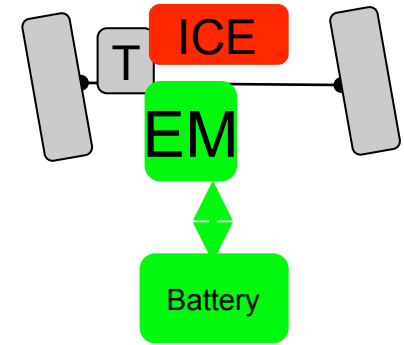
Level of Hybridization



**Micro Hybrid**  
slight efficiency improvements  
e.g. BMW 3 Efficient Dynamics

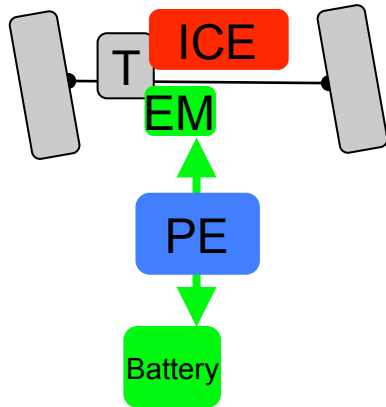


**Mild Hybrid**  
greater efficiency improvements  
e.g. Saturn Vue Hybrid

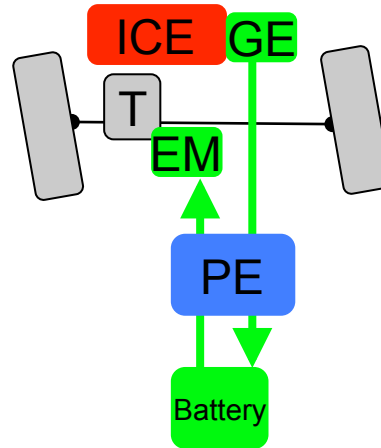


**Full Hybrid**  
optimized efficiency  
e.g. Toyota Prius

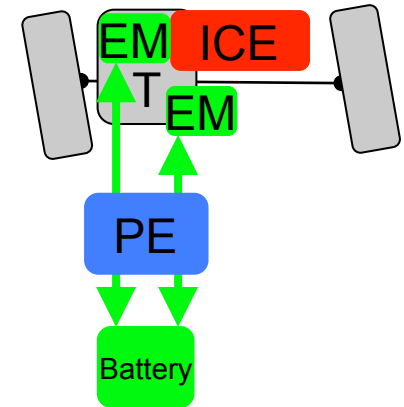
Hybridization Concept



**Parallel Hybrid**  
engine start-stop, no e-drive  
e.g. Honda Civic, Insight

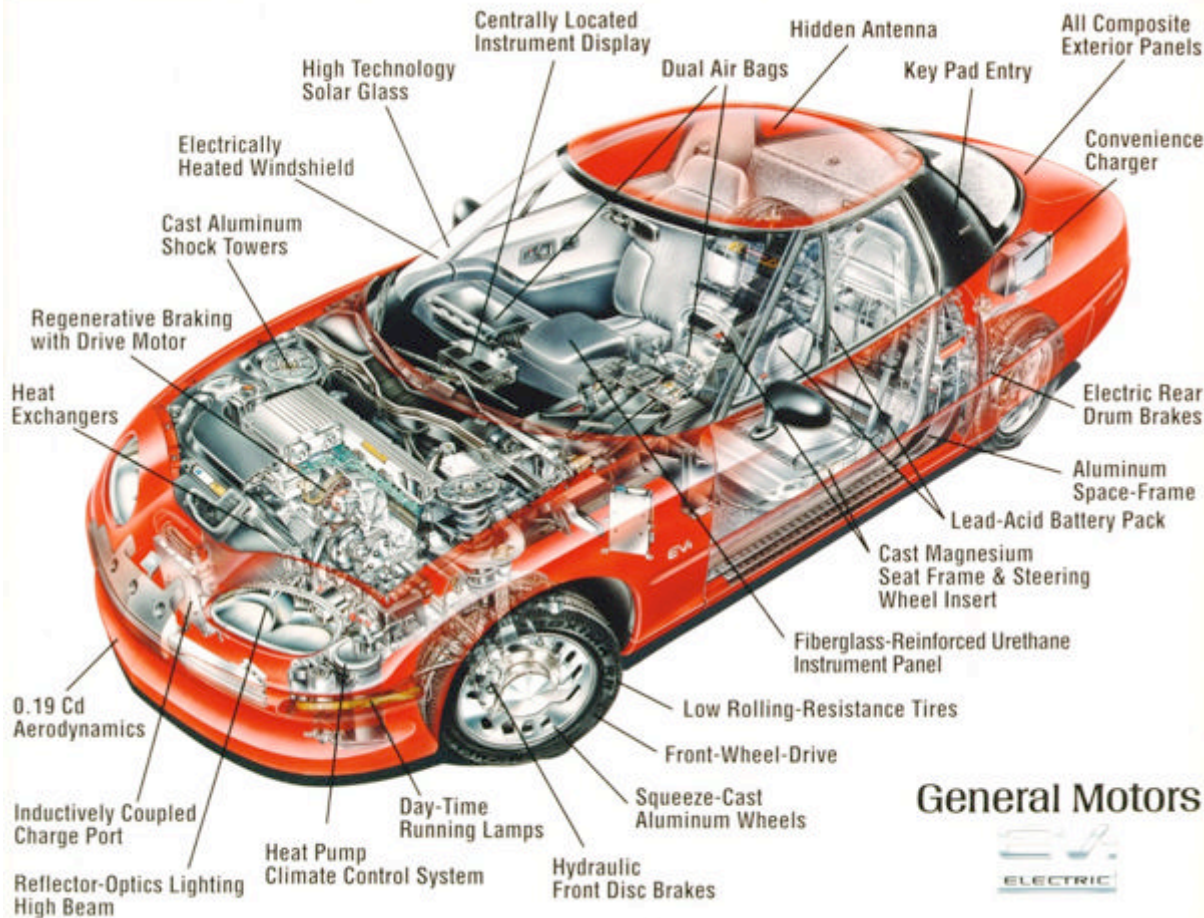


**Series Hybrid**  
all e-options, no mech linkage  
e.g., Volvo C30, Hybrid Busses



**Power-Split Hybrid**  
all e-options, relatively complex  
e.g. Toyota Prius, BMW X6

# 1990's Battery Electric Vehicles



## Example

Model: GM EV1

Concept: BEV

Body: Coupe, 2 seats

E-Range: 55-150 miles

Weight: 3,000 lbs

Output: 137 hp

Battery: Lead-Acid, 19 kWh  
NiMH, 26 kWh

Units: 1,117 (1996-1999)

Price: lease \$300-575  
(per month)

Similar: Toyota RAV 4 EV  
(1997-2003)

## Noteworthy

- Customer reaction to the EV1 was positive (see “Who Killed the Electric Car?”)
- GM believed that electric cars occupied an unprofitable niche (800 units, \$1b)
- EV1 program was subsequently discontinued in 2002, all cars were repossessed

Data source: [http://en.wikipedia.org/wiki/General\\_Motors\\_EV1](http://en.wikipedia.org/wiki/General_Motors_EV1)

Picture: <http://www.autolinedetroit.tv/journal/?p=797>

# Production Hybrid Electric Vehicles



## Example

Model: Toyota Prius

Concept: HEV (full, pwrspplt)

Body: Mid-size, 5 seats

Mileage: 50 mpg, US comb.

Weight: 3,000 lbs

Output: 134 hp

Battery: NiMH, 2 kWh

Units: 2m (Sep 2010)

Price: \$23k

Similar: Ford Escape Hybr.  
Honda Insight\*,  
many others...

\* Honda Insight is parallel hybrid

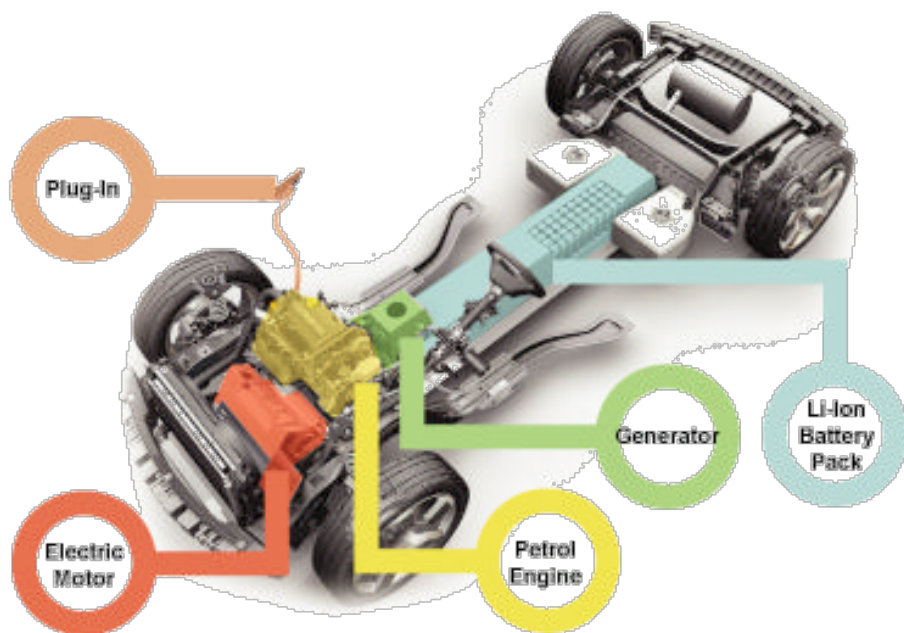
## Noteworthy

- recently surpassed by the Chevy Volt as most fuel efficient gasoline car sold in US
- sold in 70+ countries, became Japan's best selling vehicle in 2009
- buying motivation: 57% "makes statement about me," 36% "mainly fuel economy"

Data source: [http://en.wikipedia.org/wiki/Toyota\\_Prius](http://en.wikipedia.org/wiki/Toyota_Prius)

Picture: <http://www.comparecontracthire.com/blog/wp-content/uploads/2009/04/new-prius2.jpg>

# Plug-In Hybrids, “Range Extended Electric Vehicles”



## Example

Model: Chevrolet Volt

Concept: PHEV (full, pwrspplt)

Body: Mid-size, 5 seats

E-Range: 25-50 mls

Mileage: 93 / 37 mpg (e / c)

Weight: 3,800 lbs

Output: 149 hp

Battery: Li-Ion, 16 kWh

Units: 60k p.a. ('12 plan)

Price: \$40k

Similar: Toyota Prius ('12),  
Ford C-Max ('12),  
Fisker Karma ('12)

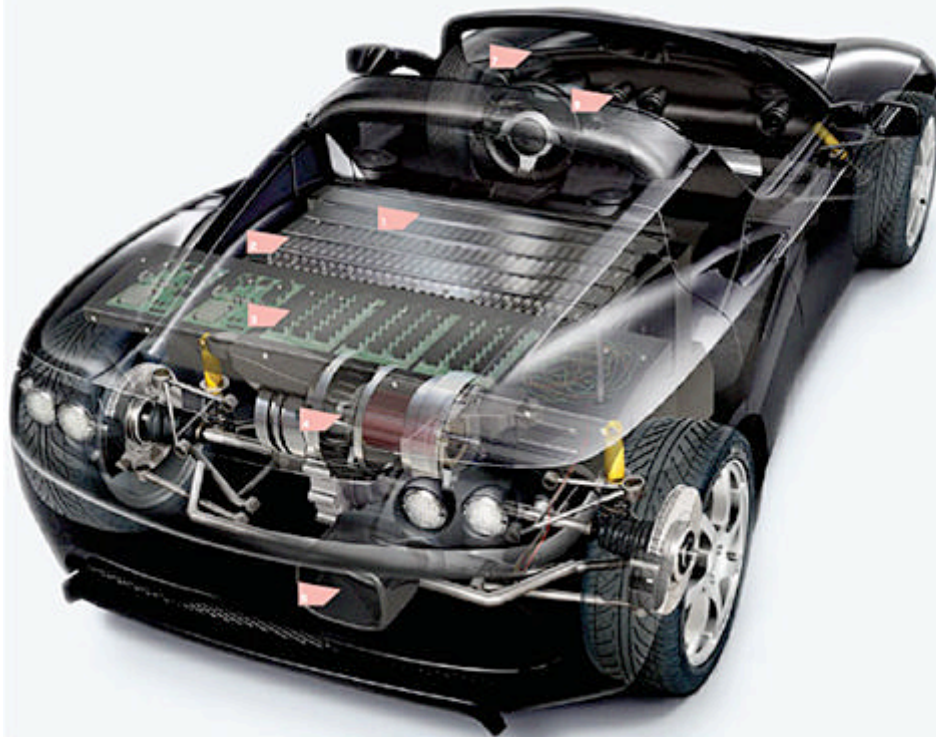
## Noteworthy

- first vehicle delivered Dec 2010, sold initially only in CA, D.C., MI, TX, NY, NJ, CT
- phone app to check fuel efficiency as well as the vehicle's current electric range
- Car & Driver Magazine for first time included electrically powered car in 10 best cars

Data source: [http://en.wikipedia.org/wiki/Chevy\\_Volt](http://en.wikipedia.org/wiki/Chevy_Volt)

Picture: [http://movementbureau.blogspot.com/photos/uncategorized/gm\\_volt\\_analysis2.png](http://movementbureau.blogspot.com/photos/uncategorized/gm_volt_analysis2.png)

# Battery Electric Vehicles “Performance Pioneers”



**1 BATTERY PACK**  
THE POWER SUPPLY IS SPLIT INTO 11 SECTORS OF 621 LITHIUM-ION CELLS. EACH SECTOR IS CONTROLLED BY ITS OWN PROCESSOR, WHICH MONITORS THE CHARGE AND DISCHARGE RATE OF EVERY CELL.

**2 SAFETY MONITORS**  
AN ACCELEROMETER, SMOKE DETECTOR, VOLTAGE METER, TEMPERATURE GAUGE, AND WATER SENSOR CAN DETECT A CRASH OR OTHER FAILURES AND SHUT THE BATTERIES DOWN TO PREVENT FIRE OR EXPLOSION.

**3 INVERTER**  
THE INVERTER USES 72 INSULATED TRANSISTORS TO TRANSFORM THE BATTERY'S DC ENERGY INTO AC POWER. IT DELIVERS ALMOST 80 PERCENT MORE POWER THAN GM'S NOW-DISCONTINUED EV1.

## ELECTRIC RIDE

THE TESLA ROADSTER PUTS THE CHARGE BACK INTO SUPERCHARGED. THE ALL-ELECTRIC, HIGH-PERFORMANCE SPORTS CAR IS POWERED BY THE SAME BATTERIES THAT RUN YOUR LAPTOP. WIRED GOT THE FIRST GUIDED TOUR. — J.O.

### 4 MOTOR

AT THE HEART OF THE AC ELECTRIC MOTOR IS A HIGH-EFFICIENCY ROTOR. THE BREAKTHROUGH: IT'S MADE OF BRAZED COPPER, WHICH IS MORE CONDUCTIVE THAN CONVENTIONAL ALUMINUM ROTORS.

### 5 COOLING

THE INVERTER'S TRANSISTORS PRODUCE VERY LITTLE HEAT, ALLOWING THE CAR TO USE LIGHTWEIGHT, ENERGY-EFFICIENT AIR COOLING, WHICH VENTS THROUGH A TAILPIPE.

### 6 HEATING

SINCE THERE IS NO CONVENTIONAL ENGINE TO PROVIDE CABIN HEATING, THE ROADSTER HAS AN ELECTRIC HEATER. ONE BONUS: IT DELIVERS HEAT IMMEDIATELY — NO WAITING FOR AN ENGINE TO WARM UP.

### 7 PARTS

TESLA HAS DEALS WITH VARIOUS MANUFACTURERS TO SUPPLY THE WINDSHIELD WIPERS, BRAKES, SUSPENSION, AND OTHER COMPONENTS — THERE'S NO NEED TO REINVENT THE HIGH-PERFORMANCE WINDSHIELD WIPER.

## Example

Model: Tesla Roadster  
Concept: BEV  
Body: Roadster, 2 seats  
E-Range: 244 mls  
Weight: 2,700 lbs  
Output: 248 hp  
Battery: Li-Ion, 53 kWh  
Units: 1,400 (Dec 2010)  
Price: \$109k

Similar: Tesla S ('12)

## Noteworthy

- first highway-capable all-electric production vehicle in the U.S., “EV Pioneer”
- to be discontinued 2012, due to tooling changes at Lotus' assembly plant in the UK
- unique charging connector, conversion to SAE J1772 standard announced

Data source: [http://en.wikipedia.org/wiki/Tesla\\_roadster](http://en.wikipedia.org/wiki/Tesla_roadster)

Picture: [http://stadium.weblogsinc.com/autoblog/videos/HiRezPics/FF\\_162\\_tesla3\\_f.jpg](http://stadium.weblogsinc.com/autoblog/videos/HiRezPics/FF_162_tesla3_f.jpg)

# Battery Electric Vehicles “Pilot Tests”

- 1 Charging Plug
- 2 Service Disconnect
- 3 Battery
- 4 Contactor Box
- 5 High Voltage Harness
- 6 Control Module
- 7 Power Electronic Unit
- 8 Electric Motor
- 9 Electric Vacuum Pump
- 10 Gearbox



## Example

Model: MINI Electric  
Concept: BEV  
Body: Compact, 2 seats  
E-Range: 100 mls  
Weight: 3,300 lbs  
Output: 204 hp  
Battery: Li-Ion, 40 kWh  
Units: 800 total  
Price: lease \$600-850  
(per month)

Similar: Ford Focus,  
Honda Jazz ('12)

## Noteworthy

- most applicants well-educated, well-off males over 35, affinity for new technology
- regenerative braking controlled via accelerator pedal (not break pedal)
- powertrain components by AC Propulsion (CA)

Data source: [http://en.wikipedia.org/wiki/Mini\\_E](http://en.wikipedia.org/wiki/Mini_E)

Picture: [http://evworld.com/images/bmw\\_mini-e\\_seethru.jpg](http://evworld.com/images/bmw_mini-e_seethru.jpg)

# Battery Electric Vehicles “Small Cars”



## Example

Model: THINK City

Concept: BEV

Body: Micro, 2+2 seats

E-Range: 100 mls

Weight: 2,300 lbs

Output: 34 kW

Battery: Li-Ion, 24 kWh

Units: 2500+ (in Europe)

Price: \$34k

Similar: Mitsubishi iMiev,  
Smart Electric,  
CT&T, Zap

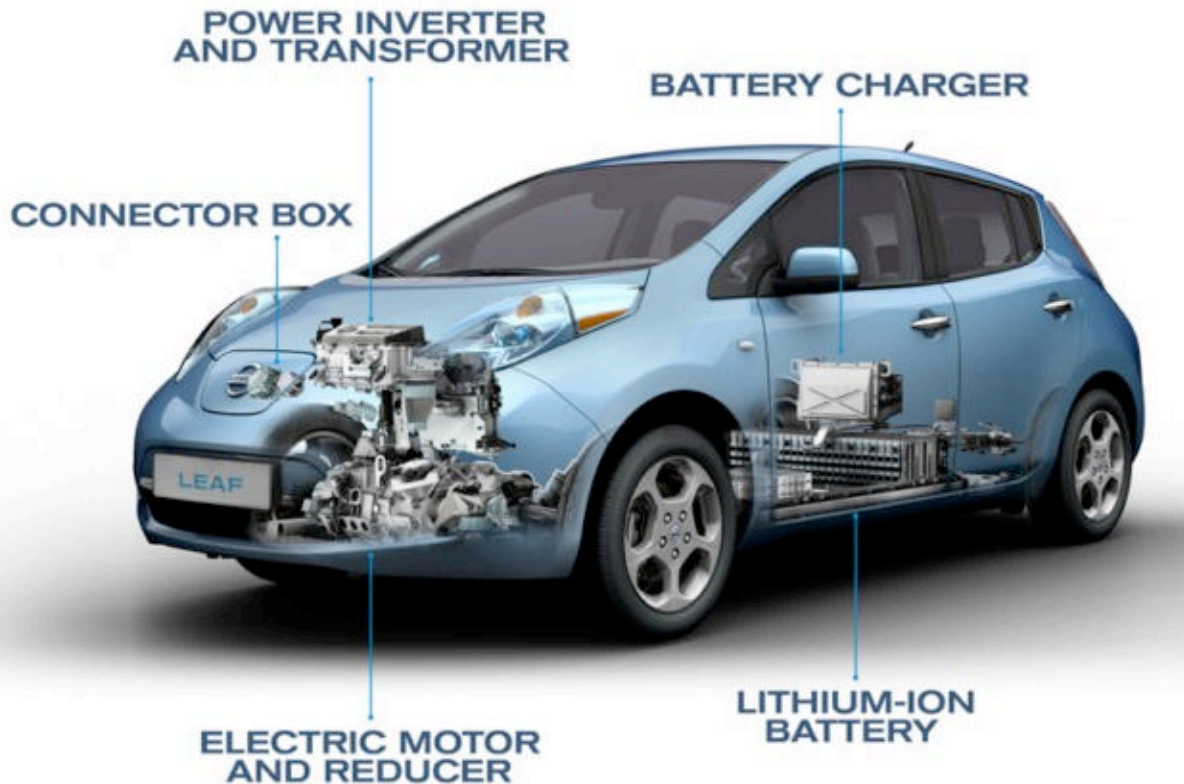
## Noteworthy

- 20 year old Norwegian company, formerly owned by Ford
- Ener1 (IN) owns 31%, supported by \$118.5 million federal grant
- delivery mainly to fleets, key markets CA, NY, D.C., IN

Data source: <http://www.pluginCars.com/think-city/review>, Think website

Picture: <http://www.pluginAmerica.org/vehicles/think-city>

# Battery Electric Vehicles “Mass Market”



## Example

Model: Nissan Leaf  
Concept: BEV  
Body: Mid-size, 5 seats  
E-Range: 73 mls  
Weight: 3,400 lbs  
Output: 110 hp  
Battery: Li-Ion, 24 kWh  
Units: 150k p.a.(plan '12)  
Price: \$33k

Similar: Ford Focus ('12),  
Mitsubishi iMiev,  
Coda Sedan ('11)

## Noteworthy

- first vehicles delivered in United States and Japan Dec 2010 (11<sup>th</sup>, 22<sup>nd</sup>)
- telematics: displays range + charging stations on a map, online driving statistics
- EPA rated combined fuel economy at 99 mpg gasoline equivalent

Data source: [http://en.wikipedia.org/wiki/Nissan\\_leaf](http://en.wikipedia.org/wiki/Nissan_leaf)

Picture: [http://2.bp.blogspot.com/\\_E2zkF4aPcRc/TMhX1-Psf7I/AAAAAAAAABog/ZgcwDXAIf1A/s1600/NISSAN+LEAF+2.jpg](http://2.bp.blogspot.com/_E2zkF4aPcRc/TMhX1-Psf7I/AAAAAAAAABog/ZgcwDXAIf1A/s1600/NISSAN+LEAF+2.jpg)

# Battery Electric Vehicles “New Asian Entries”



## Example

Model: BYD e6

Concept: BEV

Body: MPV, 5 seats

E-Range: 186 mls

Weight: 4,500 lbs

Output: up to 215+54 hp

Battery: Li-Ion, 48 kWh

Units: 40 (May '10)

Price: \$40k

Similar: Geely, Tata

## Noteworthy











- BYD is one of the largest battery manufacturers worldwide
- plans for mass production postponed, instead field test with taxis in China
- 50 vehicles for fleets in CA by end of 2011, sale to private buyers planned for 2012

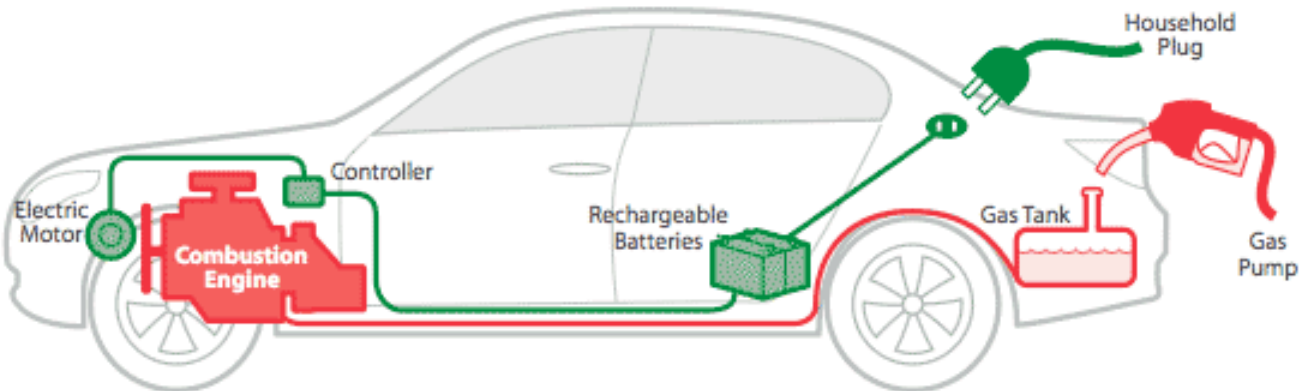
Data source: [http://en.wikipedia.org/wiki/BYD\\_E6](http://en.wikipedia.org/wiki/BYD_E6)

Picture: <http://www.autolinedetroit.tv/journal/?p=797>

# Summary – Is It Really That Simple?

## Electric vs. Gasoline

No Tailpipe Emissions 	 Greenhouse Gases/Pollution
Utility Company 	 OPEC
100+/- Mile Range 	 300+ Mile Range
Hours to Recharge 	 Minutes to Refuel
2 cents per mile 	 12 cents+ per mile



Source: <http://www.gravitycontrol.org/blog/wp-content/uploads/2009/07/gas-electric-v6.gif>