Electrical Vehicles

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2. Classification of Electrical Vehicles (EV).

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Electric Vehicles

Electric Vehicles (EVs) are vehicles propelled by electric motors that are powered by rechargeable batteries. Similarly, plug-in hybrid vehicles are run by electric power, but have a supplemental gasoline engine in the event the battery powered electric engine runs out of charge. Because EVs are not equipped (as Hybrids are) with supplemental gasoline powered engines, they have more space for a larger battery, and thus a longer battery life.

In a documentary by Nissan, it was estimated that the 5-year operating cost for a standard battery-powered vehicle to be around $1,800, while the 5-year operating cost of a gasoline car is $6,000.
Classifications of EV

Electrification

Conventional

Hybrid

Battery Electric
Definition of Electric Vehicles

EV: Electric Vehicle
BEV: Battery-only Electric Vehicle
PHEV: Plug-in Hybrid Electric Vehicle
EREV: Extended Range Electric Vehicle

PEV: Plug-in Electric Vehicle
How Does a PHEV or EREV Work?

- PHEVs overcome the range problem of BEVs
- Electric-only range vary with battery size
  - PHEV20 = 20 miles range
  - PHEV40 = 40 miles range
- PHEVs well suited for our daily driving patterns
  - 50% of all daily drives < 25 miles
  - 80% of all daily drives < 50 miles
  - Average daily driving = 33 miles
Histories:

- 1830's
  - Battery electric vehicle invented by Thomas Davenport, Robert Anderson, others - using non-rechargeable batteries
  - Davenport's car holds all vehicle land speed records until ~1900

- 1890's
  - EV's outsold gas cars 10 to 1, Oldsmobile and Studebaker started as EV companies

- 1904
  - First speeding ticket, issued to driver of an EV
  - Krieger Company builds first hybrid vehicle

- 1910's
  - Mass-produced Ford cars undercut hand-built EV's
  - EV's persist as status symbols and utility vehicles until Great Depression
History of Electric Vehicles

1891  William Morrison of Des Moines, the first successful electric automotive

1907-1939  Detroit Electric, successful electric car co.

1974  Vanguard Sebring CitiCar


1990-2000  Few thousand electric vehicles

2002  GM and DaimlerChrysler sued CARB and ZEV mandate was weakened

2006  PHEVs, retrofits: Prius, Escape

2010  GM Volt, other manufacturers
Energy Loss: City Driving

Urban Drive Cycle Energy Balance
2005 3 L Toyota Camry

Fuel Tank 100% → Engine 16% → Driveline 13%

Standby 8% → Engine Loss 76%

Driveline Losses 3%

Aero 3%
Rolling 4%
Braking 6%
Energy Loss: Highway Driving

Highway Drive Cycle Energy Balance
2005 3 L Toyota Camry

Fuel Tank: 100%

- Standby 0%
- Engine Loss 77%
- Driveline Losses 4%

Engine

23%

Driveline

19%

- Aero 10%
- Rolling 7%
- Braking 2%

POWERTRAIN

VEHICLE-Related
Energy Saving: Hybrid Systems

- Micro Hybrid Eliminates
- Fuel Tank: 100%
- Engine Standby 8%
- Engine Loss 76%
- Driveline Losses 3%
- Driveline 13%

- Full Hybrid Reduces
  - Engine downsizing
  - Decoupling of engine and wheel
- Plug-in
  - Can eliminate engine entirely

- Mild Hybrid Reduces
  - Aero 3%
  - Rolling 4%
  - Braking 6%
EV Components

Energy and Power Needs
Overview Traction-Batteries

- Lead acid-Batteries
  - Common technology, but energy-density is too low.
  - Limited cruising range, batteries are too heavy.
  - Cars only play a role in certain niches (e.g. as city car).

- New battery-technologies
  - Nickel-cadmium, Nickel-Metal Hydride, Lithium-Ion.
  - Only energy-density of Lithium-Ion batteries are sufficient to reach adequate cruising ranges. The electrical car comes out of the niche.
  - Problems: Costs, safety and life-time.

<table>
<thead>
<tr>
<th>battery type</th>
<th>power density [W/kg]</th>
<th>energy density [Wh/kg]</th>
<th>life time [years]</th>
<th>costs [EUR/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
<td>2015</td>
<td>2006</td>
<td>2015</td>
</tr>
<tr>
<td>Lead Acid Pb Pb</td>
<td>150-400$^{1,2}$</td>
<td>&lt; 250$^{3}$</td>
<td>20-30$^{1}$</td>
<td>20-30$^{1}$</td>
</tr>
<tr>
<td>Nickel Cadmium Ni-Cd</td>
<td>80-175$^{1}$ 400$^{2}$</td>
<td>&lt; 60$^{3}$</td>
<td>3$^{1}$ 2-3$^{3}$</td>
<td>3$^{1}$ 2-3$^{3}$</td>
</tr>
<tr>
<td>Nickel-Metal Hydride battery Ni-MeH</td>
<td>200-300$^{1}$ 400$^{2}$</td>
<td>60-80$^{1,2}$</td>
<td>3$^{1}$ 2-3$^{3}$</td>
<td>3$^{1}$ 2-3$^{3}$</td>
</tr>
<tr>
<td>Sodium Nickel Chloride Na-NCl2</td>
<td>155$^{1}$ 200$^{2}$</td>
<td>65-100$^{1,2}$</td>
<td>n.s.</td>
<td>5$^{1,2}$</td>
</tr>
<tr>
<td>Lithium-Ion Li-Ion</td>
<td>300$^{1}$ 400$^{2}$</td>
<td>90-120$^{1}$ 140$^{2}$</td>
<td>180$^{3}$</td>
<td>5$^{1,2}$ 10$^{2}$</td>
</tr>
</tbody>
</table>
Once the tray was in place, the batteries were installed with foam insulation to protect the batteries in the event of an accident.

- These are the two batteries which are in the front of the vehicle.
- There are two batteries which are also on each wheel well.
- Each battery is connected by the cables and terminals which we made. One cable goes from the positive terminal to the negative terminal.
- Then the next cable takes the power to the next battery.
The batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.
DC/DC Converter

- Recharges the battery through DC converter.
- The Iota DLS-55 is the most common option.

Batteries for the EV

The batteries that are used for electric cars are rechargeable.
Motor

- Generally the Brushless DC Motor is used.
- Simpler to maintain, More durable, Smaller.
- 85%-90% more efficient.
- Able to self-start.

Charger

It contains a plug that connects electric vehicle batteries to an electrical source, providing the batteries with electrical energy.
Each battery weighs 70 lbs. or 420 lbs in the trunk and 280 lbs in the front of the car plus the weight of the motor, transmission and front end of the car.
Overview On The Importance of Electric Vehicles:
HOW LONG WILL A HIGH VOLTAGE BATTERY LAST?

- Most hybrid high voltage batteries last 180,000 to 240,000 miles
- Manufacture battery warranties
  - Honda
    - 8 years / 80,000 miles
  - Toyota
    - 8 years / 100,000 miles
  - Ford
    - 8 years / 100,000 miles
  - General Motors
    - 8 years / 100,000 miles
Main components of a H2-FCV

1: Electrical Engine.
2: Fuel-Cell System.
3: High-Pressure vessels.
4: High-voltage Battery.
A example: Mitsubishi Lancer Evolution: Li-Ion Batteries and in-wheel motors

- Four synchronous in-wheel motors.
- Max. Power: 50 kW.
- Max. Torque: 518 Nm.
- Batteries: Li-on.
  - Capacity 95 AH.
  - Off-load Voltage: 336V.
  - Nominal energy: 32 kWh.
- Cruising range: 250 km.
- Top-Speed: 180 km/h.
- Curb-Wight: 1590 kg.
- CO2-Emissions: 0 (local).
- Price: Prototype.
- Series-Production planned in 2010.

- 6831 rechargeable Li-Ion batteries are used in the Tesla.
- Time to charge the batteries: 3.5 hours.
- Life-time of the batteries is enough for 100,000 miles.
The typical EV will have only 90 percent of a full charge. Thus the range stated on the Focus EV's label is 76 miles.
How to Charge the Vehicle at Home?

Charging outside: 120V (Level 1)
With 120V: 8-12 hours charging

Charging inside: 240V (Level 2)
With 240V: 1-3 hours charging
Public Charging Stations
Public Charging Stations
Public Charging Stations
Fast Charging in 15 Minutes using DC electricity

240V (AC) (Level 2)

DC connection (Level 3)

DC plug

240V (AC) (Level 2)

DC connection (Level 3)
What if you are stranded with an empty battery?
Pollutants Issues

1.1 Billion vehicles are on the road globally
88 Million will be produced in 2015 (+35m net growth)
401 ppm level of CO₂ concentration in May 2014
(>450 ppm level is critical, 2-3 ppm annual growth)
## EV Pollution

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>grams/mile</th>
<th>% of ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total organic gases</td>
<td>.011</td>
<td>0.5%</td>
</tr>
<tr>
<td>Reactive organic gases</td>
<td>.002</td>
<td>0.13%</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>.015</td>
<td>0.08%</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>.028</td>
<td>1.14%</td>
</tr>
<tr>
<td>Sulfur oxides</td>
<td>.0032</td>
<td>4.9%</td>
</tr>
<tr>
<td>Total particulates</td>
<td>.0025</td>
<td>2.6%</td>
</tr>
<tr>
<td>Particulates &lt; 10 microns</td>
<td>.0020</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

*Note: These numbers are an approximation and most probably low, maybe up to a factor of two.*
Nations Unies
Conférence sur les Changements Climatiques 2015
COP21/CMP11
Paris, France
WE MAY HAVE A CHANCE TO SURVIVE!

195 NATIONS REACH CLIMATE CHANGE ACCORD
A few other EVs

Ford Ranger

Toyota RAV4
Market of EV

City Electric Vehicles (CEV)

Ford

Nissan Hyper-mini

Speed < 60 mph  Range about 50 miles
Hybrid Electric Cars

Ford

Honda Insight

Lexus Hybrid SUV

Toyota Prius

Volvo
Today’s Market

Efficiency Rating
MPGe is the abbreviation for “miles per gallon of gasoline-equivalent.” It’s an energy efficiency metric that was introduced by the Environmental Protection Agency (EPA) in 2010 to compare the amount of energy consumed by alternative fuel vehicles to that of traditional gas-powered cars. If a vehicle uses non-liquid fuels that aren’t burned and gets its power from electricity or compressed natural gas, it’s rated in MPGe. This is the calculation you will see on an electric car’s window sticker. According to the EPA, burning one gallon of gas produces 115,000 BTUs (British thermal units). To generate the same amount of heat by way of electricity, it takes 33.7 kilowatt-hours (kWh). Kilowatt-hours is the standard energy unit for electricity.

In simplified terms, if an electric vehicle can travel 100 miles on 33.7 kWh of electricity, the EPA rates it at 100 MPGe. As you can see, this would be a very efficient vehicle, because a gas car would have to travel 100 miles per gallon to be equivalent.
Solid Growth in Electric Vehicle Sales in the US

Total number of Electric Vehicles on the Road

- EV
- PHEV

Total Numbers of US Electric Vehicles

- January 2010 to February 2012
# Average Cost of EV

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Car</td>
<td>$1,750</td>
</tr>
<tr>
<td>Cost of Electric Motor</td>
<td>$1,550</td>
</tr>
<tr>
<td>Cost of Controller</td>
<td>$1,495</td>
</tr>
<tr>
<td>Clutch less Transmission</td>
<td>$725</td>
</tr>
<tr>
<td>Clutch plates and all brackets</td>
<td>$400</td>
</tr>
<tr>
<td>10 Batteries</td>
<td>$2,250</td>
</tr>
<tr>
<td>Battery Charger</td>
<td>$1,030</td>
</tr>
<tr>
<td>Battery Cables, Terminals, Heat Shrink</td>
<td>$400</td>
</tr>
<tr>
<td>Inside Instruments</td>
<td>$225</td>
</tr>
<tr>
<td>Fuse Systems</td>
<td>$225</td>
</tr>
<tr>
<td><strong>Total Cost of Parts</strong></td>
<td><strong>$10,050</strong></td>
</tr>
</tbody>
</table>
Maintenance of Batteries:

- Learn from abused batteries.
- Failure and outage events.
- Proof internal failure behavior.

- Postmortem analysis from failed battery systems and modules.
- Disassembly of complete packs and modules for failure analysis and identification of critical spots.

- Design optimization, inherent failure tolerance levels.
- Identification of critical setups and how to avoid them.
Motor Removal:

We had to remove the muffler, radiator, alternator, air conditioner.
Tests Laboratories in USA and Canada

Auburn Hills, Michigan, USA

New Market, Toronto, Canada
Tests Laboratories in Shenzhen, China

Pack temperature chamber

Shock Tester

Vibration machine

Performance testing
Current Areas of Research

- Current research focusing on maximizing the efficiency
  » Reduce Mass.
  » Decrease material and manufacturing costs.
  » Improving the Hardware.
  » Battery – alternatives to/maximizing the nickel-metal hydride currently in use.
THANK YOU

The future really is in our hands!