Electric transportation

3315ENG Efficient Energy Systems

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History of electric cars

1821 – Michael Faraday explored that electromagnetism caused continuous rotation
1830 – The first electro motors were built
29. April 1851 – Thomas Davenport made his first drive in an electric train (technickal idea from Charles Grafton Page, 31km/h)
After 1881 – horse carriage and bicycles with electric motors
  ◦ Gustave Trouvé, exposition de l’électricité, 12km/h
  ◦ William Edward Ayrton und John Perry, 14km/h
  ◦ Werner Siemens
History of electric cars

- 29. April 1899 – Record of 105.88 km/h (with the car ‘La Jamais Contente’ by Camille Jenatzy)

- 1892–1940 in the US
  - 40% steam, 38% electric and 22% Petrol

- But the invention of the electric starter and cheaper petrol prices was the end of the electric car.
Vehicle types

- Combustion engine
- Electric cars
- Hybrid cars
Motor comparisons

- Petrol – 15% – 20%
  - Also depending on Fuel:
    - Petrol (91–99 RON (research octane rating))
    - LPG (Liquefied Petroleum Gas) – Low energy rating (102–108 RON)
- Diesel – up to 30%
- Hybrid – 15% – 97%
- Electric – up to or even over 97%
  - As energy supply/storage:
    - Batteries
    - Solar cells
    - Hydrogen cells
    - Ultra capacitor
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

http://www.hybridcars.com/electric-car
Solar cars

Mitsubishi In-wheel motor Electric Vehicle (MIEV)

Pure EV
- In-wheel motor
- Inverter
- Lithium-ion batteries

Hybrid Vehicle
- Engine / Generator
- Fuel tank (gasoline)

Fuel Cell Vehicle
- Fuel cell stack
- Fuel tank (hydrogen)

Full Hybrid

Automotive

Full Hybrid

Micro Hybrid

<table>
<thead>
<tr>
<th>Start-Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recuperation</td>
</tr>
<tr>
<td>Torque Assist</td>
</tr>
<tr>
<td>Electric Drive</td>
</tr>
<tr>
<td>Instant Heat</td>
</tr>
<tr>
<td>Electric Steering</td>
</tr>
</tbody>
</table>

http://gigaom.com/cleantech/3-steps-for-ultracapacitor-startup-success/
Recharging

http://www.streib.de/leistungen/stromtankstelle/index.html

Combined Charging

Future (?): Wireless Charging


http://www.schattenblick.de/infopool/natur/technik/ntene899.html
Wireless Charging

Diagram showing the components of wireless charging:
- Recitifying circuit
- EDLC
- Receiving antenna
- Transmitting antenna
- High-frequency power source
Recharging

http://blog.toyota.co.uk/solar-powered-ventilation-prius

Compound convex solar module for the 2004 - 2009 Toyota Prius generates 215 watts

http://www.solarelectricalvehicles.com/products.shtml
Recharging


http://hydropower4cars.com/ALL_PRODUCTS/products2.html
Charging options developed for EVs

<table>
<thead>
<tr>
<th>Level</th>
<th>Power Source</th>
<th>Power (kW)</th>
<th>Time to Charge - Based on 200 km, 28kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>120V AC; 16A</td>
<td>1.92</td>
<td>14.6 hours</td>
</tr>
<tr>
<td>Level 2</td>
<td>208-240V AC; 12A -80A</td>
<td>2.5 – 19.2</td>
<td>1.4 – 5.8 hours</td>
</tr>
<tr>
<td>Level 3</td>
<td>300-500V AC; Max 125A</td>
<td>37.5 – 62.5</td>
<td>27 – 44.8 minutes</td>
</tr>
<tr>
<td>JFE</td>
<td>300-500V AC; 500-600 A</td>
<td>150 - 300</td>
<td>5.6 – 11.2 minutes</td>
</tr>
</tbody>
</table>
Tesla Roadster – Full electric car

375 volt AC induction air-cooled electric motor with variable frequency drive.

<table>
<thead>
<tr>
<th>Torque</th>
<th>273 lb-ft at 0-5,400 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>295 lb-ft at 0-5,100 rpm</td>
</tr>
<tr>
<td>Horsepower</td>
<td>302 hp (225 kW) at 5,000-6,000 rpm</td>
</tr>
<tr>
<td></td>
<td>299 hp (223 kW) at 4,400-6,000 rpm</td>
</tr>
<tr>
<td>Max rpm</td>
<td>14,000 rpm</td>
</tr>
<tr>
<td>Acceleration</td>
<td></td>
</tr>
<tr>
<td>Top Speed</td>
<td>125 mph</td>
</tr>
<tr>
<td>0 to 60 mph</td>
<td>3.9 seconds</td>
</tr>
</tbody>
</table>

Range 245 miles = 394.29 km
The Tesla Roadster has a recharging rate of 1 h/90 km. Thus, a complete recharge from empty to full would take approximately 4 hours.

In the USA, by using a 120V outlet on a 15 A circuit breaker, the charging rate would be 1h/8.0 km. Accordingly a complete recharge from empty to full would require 48 hours.
## EV batteries comparisons on price and weight and ranges

<table>
<thead>
<tr>
<th></th>
<th>Lead Acid</th>
<th>NiMh</th>
<th>Lithium-ion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial purchase cost Wh/AU$</strong></td>
<td>8~20.2</td>
<td>3.15</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>Wh/Kg Energy density</strong></td>
<td>35~80</td>
<td>30~80</td>
<td>100~250</td>
</tr>
</tbody>
</table>

**Assume the fuel efficiency requirement is 140 Wh/Km**

<table>
<thead>
<tr>
<th></th>
<th>AU$</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>100km (14 kWh)</strong></td>
<td>693~1750</td>
<td>4445</td>
<td>8235</td>
</tr>
<tr>
<td><strong>Weight (Kg)</strong></td>
<td>175~400</td>
<td>175~467</td>
<td>56~140</td>
</tr>
<tr>
<td><strong>200km (28 kWh)</strong></td>
<td>1386~3500</td>
<td>8890</td>
<td>16470</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>350~400</td>
<td>350~934</td>
<td>112~280</td>
</tr>
<tr>
<td><strong>300km (36 kWh)</strong></td>
<td>2079~5250</td>
<td>13335</td>
<td>24705</td>
</tr>
<tr>
<td><strong>Weight (Kg)</strong></td>
<td>525~1200</td>
<td>525~1400</td>
<td>168~420</td>
</tr>
</tbody>
</table>
Energy uses and losses in a vehicle

- Standby/Idle: 17.2%
- Accessories: 2.2%
- Driveline Losses: 18.2%
- Engine Losses: 5.6%
- 62.4%

- Aerodynamic Drag: 2.6%
- Rolling Resistance: 4.2%
- Inertia: 5.8%
- Braking: 5.8%
Energy uses and losses in a vehicle

- **Internal Combustion Engine**
  - Energy Input: 100%
  - Heat Loss: 62%
  - Idle Loss: 17%
  - Driveline Loss: 6%
  - Energy Output: 15%

- **Electric Motor**
  - Energy Input: 100%
  - Driveline Loss: 6%
  - Electric Resistance: 14%
  - Energy Output: 80%

5–6x More Efficient on Energy to Wheels Basis
Honda Civic Hybrid

- 1.5 litre SOHC i-VTEC engine

- 82kW @ 5500rpm and 172Nm @ 1000-3500rpm

- Fuel consumption – combined 4.4 (L/100km)

  Kerb weight (kg) 1285
Toyota Prius

- What is inside the Prius Hybrid?
Toyota Prius

Secondary engine power
- Maximum power kW 73

- Fuel consumption – combined 3.9 (L/100km)

Kerb weight (kg) 1420
What is the electric system of the Prius Hybrid?
Reference

- J. L. Kirtley, “Electric Power Principles”, Wiley, 2010,
- Austin Hughes, “Electric Motors and Drives – Fundamentals, Types and Applications,” Elsevier
- www.wikipedia.de
- http://www.patchn.com
- http://www.moeller.net