The Transportation Challenge

http://www.pewclimate.org/technology/overview/transportation

Transportation Energy Use by Mode (2006)

Source: DOE, *Transportation Energy Data Book*, Table 3.6, 2008.
Global Demand Projections

Alternative transportation fuels

hydrogen – fuel cells
efficiency of hydrogen as energy carrier

electric – batteries
plug-ins

hybrid vehicles
off-grid – e.g. Prius
plug-in hybrids

biofuels
ethanol, methanol
biodiesel

Concept of ‘well-to-wheels’ efficiency as measure
Hydrogen fuel cell

Plug-in battery electric
Hydrogen sources:

*steam – methane*

\[ 2\text{H}_2\text{O} + \text{CH}_4 \rightarrow \text{CO}_2 + 3\text{H}_2 \]

At high temperatures (700 – 1100 °C) and in the presence of a metal catalyst, steam reacts with methane to yield carbon dioxide and water.

Hydrogen and carbon dioxide gases are compressed and separated.

*coal gasification*

coal \( \rightarrow \text{CO, CO}_2, \text{CH}_4, \text{H}_2 \) (syngas)

Heating in absence of oxygen (in situ coal gasification, e.g.)

Hydrogen is separated from compressed syngas.

*electrolysis*

\[ 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \]

Requires direct electrical current; oxygen and hydrogen collect at anode and cathode.
Tesla Roadster
performance with a clean conscience

- 0-60 mph in 3.9 seconds
- 244-mile range
- 2x more efficient than a Prius

“Hi-performance” plug-in

2009 Model S Base *Price* $49,900
The following table shows the well-to-wheel energy efficiency of several types of high-efficiency cars – including an efficiency estimate of the Tesla Roadster – based on the measured performance prototypes.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Example Car</th>
<th>Source Fuel</th>
<th>Well-to-Station Efficiency</th>
<th>Vehicle Mileage</th>
<th>Vehicle Efficiency</th>
<th>Well-to-Wheel Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Engine</td>
<td>Honda CNG</td>
<td>Natural Gas</td>
<td>86.0% 35 mpg</td>
<td>0.37 km/MJ</td>
<td>0.318 km/MJ</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Fuel Cell</td>
<td>Honda FCX</td>
<td>Natural Gas</td>
<td>61.0% 64 mi/kg</td>
<td>0.57 km/MJ</td>
<td>0.348 km/MJ</td>
<td></td>
</tr>
<tr>
<td>Diesel Engine</td>
<td>VW Jetta Diesel</td>
<td>Crude Oil</td>
<td>90.1% 50 mpg</td>
<td>0.53 km/MJ</td>
<td>0.478 km/MJ</td>
<td></td>
</tr>
<tr>
<td>Gasoline Engine</td>
<td>Honda Civic VX</td>
<td>Crude Oil</td>
<td>81.7% 51 mpg</td>
<td>0.63 km/MJ</td>
<td>0.515 km/MJ</td>
<td></td>
</tr>
<tr>
<td>Hybrid (Gas/Electric)</td>
<td>Toyota Prius</td>
<td>Crude Oil</td>
<td>81.7% 55 mpg</td>
<td>0.68 km/MJ</td>
<td>0.556 km/MJ</td>
<td></td>
</tr>
<tr>
<td>Electric</td>
<td>Tesla Roadster</td>
<td>Natural Gas</td>
<td>52.5% 110 Wh/km</td>
<td>2.18 km/MJ</td>
<td>1.145 km/MJ</td>
<td></td>
</tr>
</tbody>
</table>
Ships:
Heavier fuel oil, coal(?) are feasible alternatives

Airplanes:
biofuels - methanol, ethanol – lower energy density
biodiesel – experimentation is on-going
hydrogen – storage systems may be too heavy