Big Solutions for Big Problems

Automotive World Briefing

The Global Oil Paradox: Transforming the Automotive Industry

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Director

21st October, 2008
E4tech’s perspective

- Consultancy, established 1997
- Based in the UK and in Switzerland
- Strategy, business support, technology review and policy input
- Technically-informed, business/policy focused
- Clients include industrial companies, government, technology startups, investors

---|---|---|---|---|---
![Fuel cells](image1.png) | ![Hydrogen](image2.png) | ![Sustainable Buildings](image3.png) | ![Bioenergy](image4.png) | ![Energy Systems](image5.png) | ![Novel Energy](image6.png)
Today

Big problems

System level options

Big solutions?
Road transport is facing several megatrends

Energy costs

Energy security

Transport emissions & climate change

Ref.: DOE/EIA

Ref.: BP

Pressure for changes to the road transport energy system
Ignoring the future will hurt you in the end

Coming down the line...

Evening Star
Born: 1960, UK
Life expectancy: until 1980s

Died: 1965
Cause of death: diesel

US SUV sales tumble

CAFE regulations

mpg (mile per gallon)

CAFE (passenger car)
CAFE (passenger car and light truck)
CAFE (light truck)

Ref.: NHTSA

Ref.: Motor Intelligence
may want to include some sales figures of Toyota overtaking the big three and perhaps their product mix to ram this home?

David Hart, 19/10/2008
Big problems

System level options

Big solutions?
either last slide of previous section or first slide of this one should at least outline the links between and potential decoupling of emissions/security of supply/fuel type, as the first slide simply says resources and climate change are a problem.
An energy system response is required.

Policy makers

Vehicle manufacturers

Energy companies

Researchers

Independent technology innovators

Professional investors

Energy demand

Vehicle km
- Driver choice
- Spatial planning
- Access restrictions
- Telematics
- Support alternatives
- etc

Vehicle energy requirements
- Lighter weight
- Driving style
- Speed restrictions
- Purchasing behaviour
- etc

Energy supply

Powertrain
- Improved ICE
- Mild / full hybrid
- Plug in hybrid
- Battery electric
- Fuel cell electric
- etc

Fuel
- More diesel
- Convergent fuels
- Biofuels
- Electricity
- Hydrogen
- etc
ellipse is to suggest that demand is someone else's discussion, we'll focus on supply?

David Hart, 19/10/2008
## Supply-side options for changes to the energy system

### Qualitative assessment of main supply side options

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Fossil liquid</th>
<th>1G biofuels</th>
<th>2G+ biofuels</th>
<th>Gasoline / diesel</th>
<th>Electricity / fossil</th>
<th>Electricity</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powertrain</td>
<td>Efficient ICE</td>
<td>ICE</td>
<td>ICE</td>
<td>Hybrid EV</td>
<td>Plug in Hybrid EV</td>
<td>EV</td>
<td>Fuel cell vehicle</td>
</tr>
<tr>
<td>CO2 reduction per vehicle</td>
<td>+</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Primary energy availability</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Primary energy security</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Cost per km potential</td>
<td>++</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Infrastructure upheaval</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>?</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Notes
- No regrets move, but limited long term potential
- Limited overall resource
- Sustainability concerns
- Interesting potential, some CO2 issues remain
- Potentially useful transition technology
- Quite low CO2 with good range, Cost?
- Potentially low CO2. Cost? Range? Infrastructure?
- Potentially low CO2. Cost? Infrastructure?
2G+ biofuels are developing fast, but commercial production is 5-10 years away

<table>
<thead>
<tr>
<th>Development status</th>
<th>Basic and applied R&amp;D</th>
<th>Demonstration</th>
<th>Pre-commercial</th>
<th>Supported commercial</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignocellulosic ethanol</td>
<td></td>
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<tr>
<td>Lignocellulosic butanol</td>
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<td></td>
<td></td>
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<tr>
<td>Gasification -FT liquids</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pyrolysis derived fuels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Algae</td>
<td></td>
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</tr>
</tbody>
</table>

Verenium (lignocellulosic ethanol)

Pyrolysis oil

Algae production
Some EV/Hybrids are already commercial and plug-ins are being prepared for launch in the coming 5 years.

- **2008**
  - Honda Civic
    - Hybrid, Now
  - Ford Escape
    - Hybrid, Now
  - Smith Vans and Trucks
    - Electric, Now

- **2009**
  - Tesla Roadster
    - Electric, 2009
  - Toyota Prius
    - Plug-In, 2009?
  - Smart EV
    - Electric, 2009?

- **2010**
  - Fisker Karma
    - Plug-In, 2010
  - Chevy Volt
    - Plug-In, 2010+?
  - BYD – F3DM
    - Plug-In, 2010+?

- **...20XX**
Plug-in hybrids and battery EVs present challenges and opportunities at the energy system level

Plug-in HEV and battery vehicles might link two critical elements of the whole energy system

**Challenges**

- The build up of new power capacity is problematic
- System peaks: Charging a car is worse than the infamous kettle!
- Need to create a charging infrastructure
- Risk of bottlenecks in distribution/transmission
- Need to find cost-environmental optimal solutions. Is it going to be really green?

**Opportunities**

- Demand Side Management
  - Support the penetration of renewable: fuel the cars when the wind is blowing
  - Postpone new plant investments
- Vehicle-to-grid (V2G): a new business model for drivers, fleet management and utilities
  - Provide ancillary services to the grid

![Emissions - 2020 UK grid mix 100% electric driving](chart.png)

![Generation (GW)](graph.png)
Hydrogen fuel cell vehicles are the main alternative to (H)EVs, though mass rollout is not expected before 2020 in any case

<table>
<thead>
<tr>
<th>EV &amp; plug-in HEV advantages</th>
<th>Fuel cell / hydrogen advantages</th>
</tr>
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<tbody>
<tr>
<td>• EV travels further per unit of primary energy (battery more efficient than hydrogen)</td>
<td>• Fuel cell plus hydrogen storage is lighter than batteries for a given vehicle range</td>
</tr>
<tr>
<td>• Hybridisation increases range, but may reduce CO2 benefits</td>
<td>• Hydrogen refuelling is quicker than EV recharging</td>
</tr>
<tr>
<td>• Infrastructure requirements simpler for EV than H2, especially for HEV</td>
<td>• Less toxic materials are required for fuel cells than batteries</td>
</tr>
<tr>
<td>• Could provide electricity system advantages</td>
<td>• Electricity system may not be able to cope with EVs, but H2 can be stored</td>
</tr>
<tr>
<td>• Currently lower cost than FCV, battery cost dominates</td>
<td>• Cost growth is not linear with vehicle range / performance</td>
</tr>
<tr>
<td>• Rollout planned in coming 10 years</td>
<td>• Rollout planned after 2020</td>
</tr>
</tbody>
</table>

In practice both options are being pursued. They may be complements or substitutes.
Big problems

System level responses

Big solutions?
Options become solutions as they migrate from niches to the regime and landscape levels

The Multi Level Perspective of System Transformation

1. Ideas develop within niches
2. A dominant design emerges
3. Landscape changes put pressure on the existing regime, opening it up
4. The new design breaks through, causing changes to the regime
5. The new regime influences the landscape

Source: Geels and Schot, 2007
Not sure how this will be presented, but maybe an idea to mention it earlier as suddenly getting into innovation theory may take audience time to adjust to.

David Hart, 19/10/2008
All aspects of the regime level will be altered by changes to vehicle energy systems

<table>
<thead>
<tr>
<th></th>
<th>Observations for new vehicle energy systems</th>
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</table>
| **Science**               | • New disciplines coming to the fore – e.g. biology, materials science.  
  • Breakthroughs still required to achieve cost targets e.g. FC materials |
| **Technology**            | • Vehicle design will alter to accommodate new energy systems  
  • Links between vehicle and off-board technology will be crucial (e.g. charging infrastructure)  
  • Scale economics for each energy system are different  
  • Agile new companies will innovate where larger firms do not |
| **Policy**                | • Long term, clear, outcome-focused policy required by actors  
  • CO2 increasingly recognised by policy instruments, though road transport CO2 is hard to reduce compared with some other sectors  
  • Energy security less clearly supported by policy than government edicts (e.g. nuclear) |
| **Culture**               | • How and where vehicles are used may change as electrification provides new functions  
  • Vehicle range expectations may adjust  
  • Is the age of emotional attachment to cars coming to an end? |
| **Industry**              | • Weak profitability threatens all R&D  
  • Deep pockets will be needed by all actors  
  • Plug in vehicles and hydrogen electrolysis open the door for power utilities  
  • New powertrains may enable OEMs to regain control of servicing over the vehicle life |
| **Markets**               | • Consumers may purchase part of the vehicle and lease the rest – e.g. batteries, platinum  
  • In a multi fuel/powertrain future there may be many more submarkets with dedicated products (e.g. city, suburban, long distance, rural) |
In summary….

- The pressure for change is too big to ignore
- Change needs to take place at the vehicle energy system level
- There are numerous technical options; none is the obvious winner, though some are closer to market than others
  - Improved internal combustion engines are an obvious first step
  - Biofuels likely not to be the silver bullet
  - Hydrogen fuel cells imply a major system revolution
  - Plug-in vehicles require massive demand side management
  - Plug-in hybrids likely to play a bridging role, whatever the end game
- After a century of little change, the regime and ultimately the landscape of vehicle energy systems is changing.
- This implies significant changes in far more than just science and technology.