Sustainable Technology Project

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Fuel efficient, but sustainable?
Safe, but sustainable?

SUSTAINABILITY?

- Energy
- Materials
- Environment
- Emissions
- Safety
- Legality
- Social acceptance
- Space
- Economics
Triple Bottom Line accounting

Corporate sustainability report:
- **Financial bottom line**
- **Social / ethical performance**
- **Environmental performance**
  - *Dow Jones Sustainability Index*
  - **But what can Engineer do?**
  - *Decouple – unpack meaning*
Macro-economic view: the Three Capitals

- Natural capital (Planet)
  - Atmosphere, land, fresh water, oceans, bio-sphere, material and energy resources

- Manufactured and financial capital (Prosperity)
  - Built environment, Industrial capacity, Financial health, (GDP)

- Human and Social capital (People)
  - Education, health, skills, knowledge, happiness

Comprehensive capital

- Sustainable development = Growth in Comprehensive capital
- How link to projects claiming Sustainable Development?
Articulations of sustainable development

Many single actions ("articulations") claim to support sustainable development

<table>
<thead>
<tr>
<th>Motivation (Prime objective)</th>
<th>Articulation</th>
<th>Unintended consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce dependence on oil</td>
<td>Bio-fuels, Bio-polymers</td>
<td>Competition with food production (People)</td>
</tr>
<tr>
<td>Stimulate low-carbon economy</td>
<td>Carbon taxes</td>
<td>Increase energy price (Prosperity)</td>
</tr>
<tr>
<td>Stimulate circular materials economy</td>
<td>Mandatory recycling</td>
<td>Inhibits use of advanced materials (Planet)</td>
</tr>
</tbody>
</table>

Each articulation has a **Prime Objective** with a physical scale, time scale.
The Stakeholders

Stakeholders

- Who are they?
- What are their concerns?
- What power do they have?

- Government
- The public
- Local communities
- Owners
- Manufacturers
- Suppliers
- Trade Unions
- Customers
- Lobbyists
- Investors
- National press
- Managers, colleagues, team

Stakeholder diagram
Map of Articulations

- Articulations conflict

What do we learn?

Group under

- Materials
- Environment
- Design
- Regulation
- Society
- Economics
Analysing an “articulation”

- Design and Manufacture
- Material Supply Chain
- Environment and Energy
- Regulation, Legislation
- Society, Social Equity
- Economics
Analysing an “articulation”

1. Objective
2. Stakeholders
3. Fact-finding
4. Debate impact
5. Reflect

Reflect

Impact on capitals involves judgment

Factual questions – research systematically

Define the articulation

Step 5

Sustainable development?

Natural capital

Manufactured capital

Human capital

Design and Manufacture

Materials, Supply chain

Environment and energy

Regulation, Legislation

Economics

Society, Social Equity

Prime Objective
- Motivation?
- Scale?
- Timing?

Stakeholders
- Who?
- What concerns?
- What power?
The electric car – Step 1: Prime objective

Background

Global car production: 60 million units per year
15% of global fossil fuel CO₂ release comes from cars

Governments offer incentives: 20% electric by 2020

Prime objective and scale

- Decarbonize road transport
- 16 million cars/year by 2020
Step 2: Stakeholders and concerns

- National and local government
  - carbon targets

- Car makers and distributors
  - sales

- Labor Unions
  - employment, rights

- Drivers, Automobile Associations
  - range anxiety, cost

- Environmental campaigners
  - carbon footprint
Step 3: Fact-finding

Students (in groups) research facts

- Material Supply Chain
- Design
- Environment
- Regulation, Legislation
- Society, Social equity
- Economics
Fact-finding: Materials

<table>
<thead>
<tr>
<th>Bill of materials</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>790</td>
</tr>
<tr>
<td>Cast iron</td>
<td>151</td>
</tr>
<tr>
<td>Wrought aluminum (10% recycle)</td>
<td>30</td>
</tr>
<tr>
<td>Cast aluminum (35% recycle)</td>
<td>64</td>
</tr>
<tr>
<td>Copper / Brass</td>
<td>26</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.3</td>
</tr>
<tr>
<td>Glass</td>
<td>39</td>
</tr>
<tr>
<td>Thermoplastic polymers</td>
<td>94</td>
</tr>
<tr>
<td>Thermosetting polymers</td>
<td>55</td>
</tr>
<tr>
<td>Rubber</td>
<td>33</td>
</tr>
<tr>
<td>Platinum, exhaust catalyst</td>
<td>0.007</td>
</tr>
<tr>
<td>Electronics, emission control</td>
<td>0.27</td>
</tr>
<tr>
<td>Neodymium</td>
<td>1.5</td>
</tr>
<tr>
<td>Lithium</td>
<td>4.8</td>
</tr>
</tbody>
</table>

16 million cars per year, 4.8 kg Lithium per car = 76,000 tonnes per year

Lithium

<table>
<thead>
<tr>
<th>Producing Nation</th>
<th>Tonnes/year 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>12,600</td>
</tr>
<tr>
<td>Australia</td>
<td>11,300</td>
</tr>
<tr>
<td>China</td>
<td>5,200</td>
</tr>
<tr>
<td>Bolivia</td>
<td>5,000</td>
</tr>
<tr>
<td>Argentina</td>
<td>3,200</td>
</tr>
<tr>
<td>World</td>
<td>34,000</td>
</tr>
</tbody>
</table>

Li demand = 230% present world production
Fact-finding: Design

Alternative batteries?
Seek high energy density (MJ/kg)

Best battery
Lithium-ion
0.6 MJ/kg

Factor 75

Gasoline
Fact-finding: Regulation

• US CAFÉ Standard – *Fleet mileage standard*

• EU Automotive Fuel Efficiency Standard – *Fleet mileage standard*

• EU End-of-Life Vehicles Directive – *85% recycled by 2015*

• EU Battery Directive – *No batteries to landfill*
Environment: Can Prime Objective be met?

Decarbonize road transport?

Charge vehicle from the National Grid, gas / coal fired.

- CO₂ footprint, gas fired power ≈ 140 g CO₂/ MJ
- Delivered energy to propel small car ≈ 0.6 MJ / km
- Efficiency of battery – electric motor set ≈ 85%

Carbon footprint of electric car ≈ 140 x 0.6 / 0.85
≈ 100 g CO₂ / km
Step 3: Fact-finding

Students (in groups) research facts

- Material Supply Chain
  - Neodymium
  - Lithium
- Design
  - Magnets
  - Batteries
- Environment
  - CO2 footprint
  - Recycling
- Regulation, Legislation
  - Battery Directive
- Society, Social equity
  - Range anxiety
- Economics
  - Price
### Step 4 Integration – impact on the 3 capital

<table>
<thead>
<tr>
<th></th>
<th>NATURAL CAPITAL</th>
<th>HUMAN CAPITAL</th>
<th>MANUFACTURED CAPITAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MATERIAL</strong></td>
<td>• Drain on scarce resources (rare earths)</td>
<td></td>
<td>• Supply chain for lithium, neodymium inadequate</td>
</tr>
<tr>
<td></td>
<td>• Potential for recycling high</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ENVIRONMENT</strong></td>
<td>• 100 g CO₂/km = Objective not achieved</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Gain possible if grid decarbonised</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REGULATION</strong></td>
<td>Mandatory recycling</td>
<td></td>
<td>• Lack of recycling infrastructure for lithium, neodymium</td>
</tr>
<tr>
<td><strong>SOCIETY</strong></td>
<td></td>
<td>• Range anxiety not met</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Creates jobs</td>
<td></td>
<td>• High cost of car an obstacle</td>
</tr>
<tr>
<td><strong>DESIGN</strong></td>
<td></td>
<td></td>
<td>Technically proven</td>
</tr>
</tbody>
</table>
Step 5 – Reflection

- Establish infrastructure
  - Long term – 25 years
  - Establish infrastructure
    - Low carbon grid,
    - Material supply chain
    - Li and Nd recycling facilities

- Re-think (re-define?) car use

- Short term – 7 years
  - Not in envisaged scale and time
Running the project

Instructor introduces project
- Students in groups
  - Discuss as class
- Students in groups
  - In-class debate
  - Open question to class

Steps 1 and 2
- Review Stakeholders

Steps 3 and 4
- Fact-finding
- Debate Integration