Unit 23.

Sustainability and Material efficiency

- adapting to resource constraints

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TEACHING RESOURCES

This lecture unit is part of a set created by Mike Ashby to help introduce students to materials, processes and rational selection.

The Teaching Resources website aims to support teaching of materials-related courses in Design, Engineering and Science.
Resources come in various formats and are aimed primarily at undergraduate education.
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Outline

- *The global vision of sustainable development*
  - ***– Definition – Triple bottom line – The three Capitals***
- *Specific "articulations" of sustainable technology –* ***Examples – conflicts***
- *Three key efficiencies –* ***Energy efficiency – Bio-efficiency – Material efficiency***
- *Material efficiency –* ***Why is it low? What are the boundary conditions?***
- *A DB to support sustainable selection of materials* ***– content - use***

Resources

- Ashby, M. (2012) **"Materials and the Environment", 2nd Edition** Chapters 7 – 11
- Mulder, K., Ferrer, D. and Van Lente, H. (2011) **"What is sustainable technology"** Greenleaf Publishing, Sheffield, UK.
- References listed in Notes for this frame

Defining "Sustainability"

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

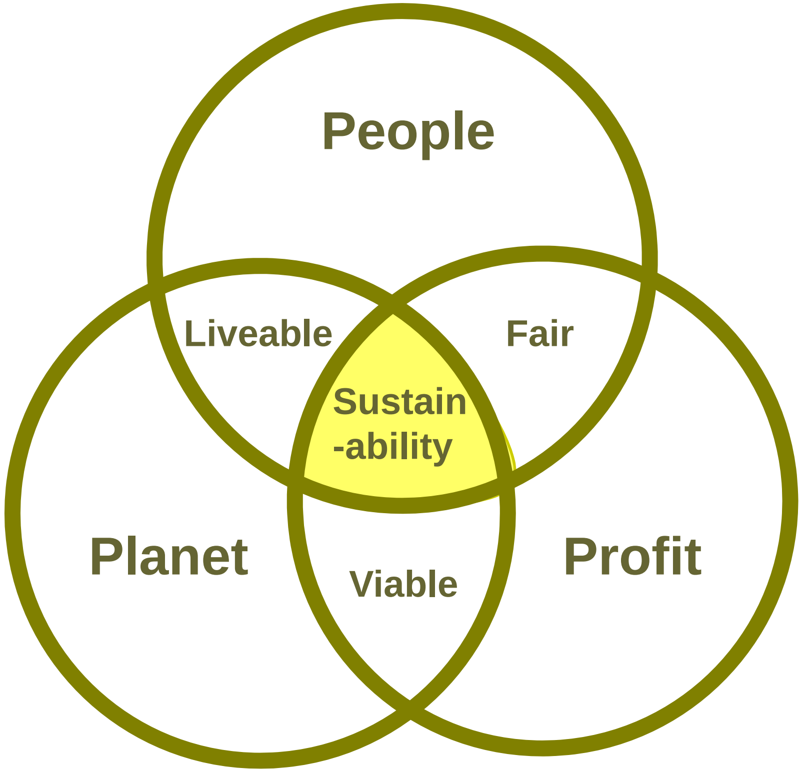
Report of the Brundtland commission of the UN, 1987

Key concepts

- Emphasis on future generations
- Joint, world-wide responsibility
- What needs, and who defines them?

Where do materials fit in?

Another view: the "triple bottom line"



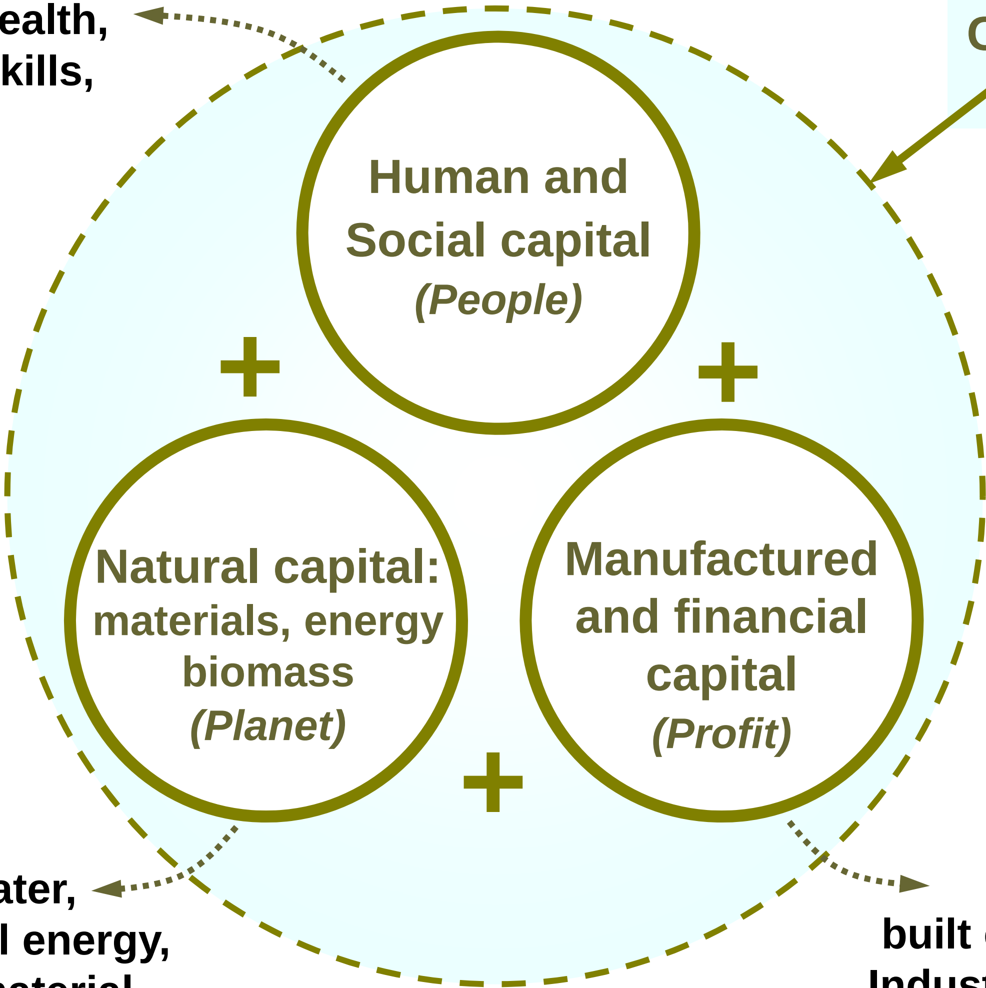
- *Noble but vague – What can a designer do?*
- *Again - where do materials fit in?*

- *Decouple the circles – unpack their meaning*

The economist's view: 3 capitals

Education, health, happiness, skills, accumulated knowledge

Comprehensive capital



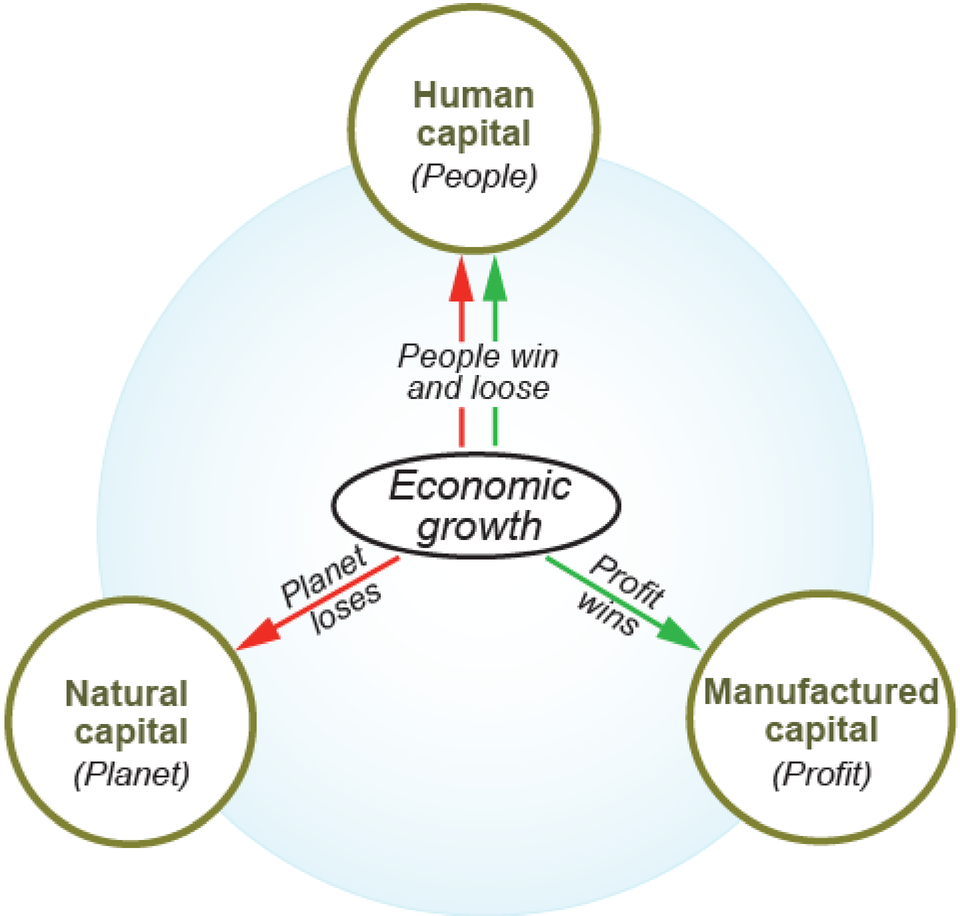
- **"Weak" sustainability** *positive growth in comprehensive capital*
- **"Strong" sustainability** *positive growth in all three capitals*

Atmosphere, land, fresh water, oceans, fossil energy, bio-sphere, material resources

Institutions, built environment, Industrial capacity, Financial institutions (GDP)

What drives change in the 3 C's?

- **Economic growth: the central focus of government and business**



- **Can it be sustainable?**

Focus on growth

- **Creates profit**
- **Creates wealth for some, disadvantages others**
- **Draws on natural resources, creates waste**

How rebalance?

Articulations of sustainable technology

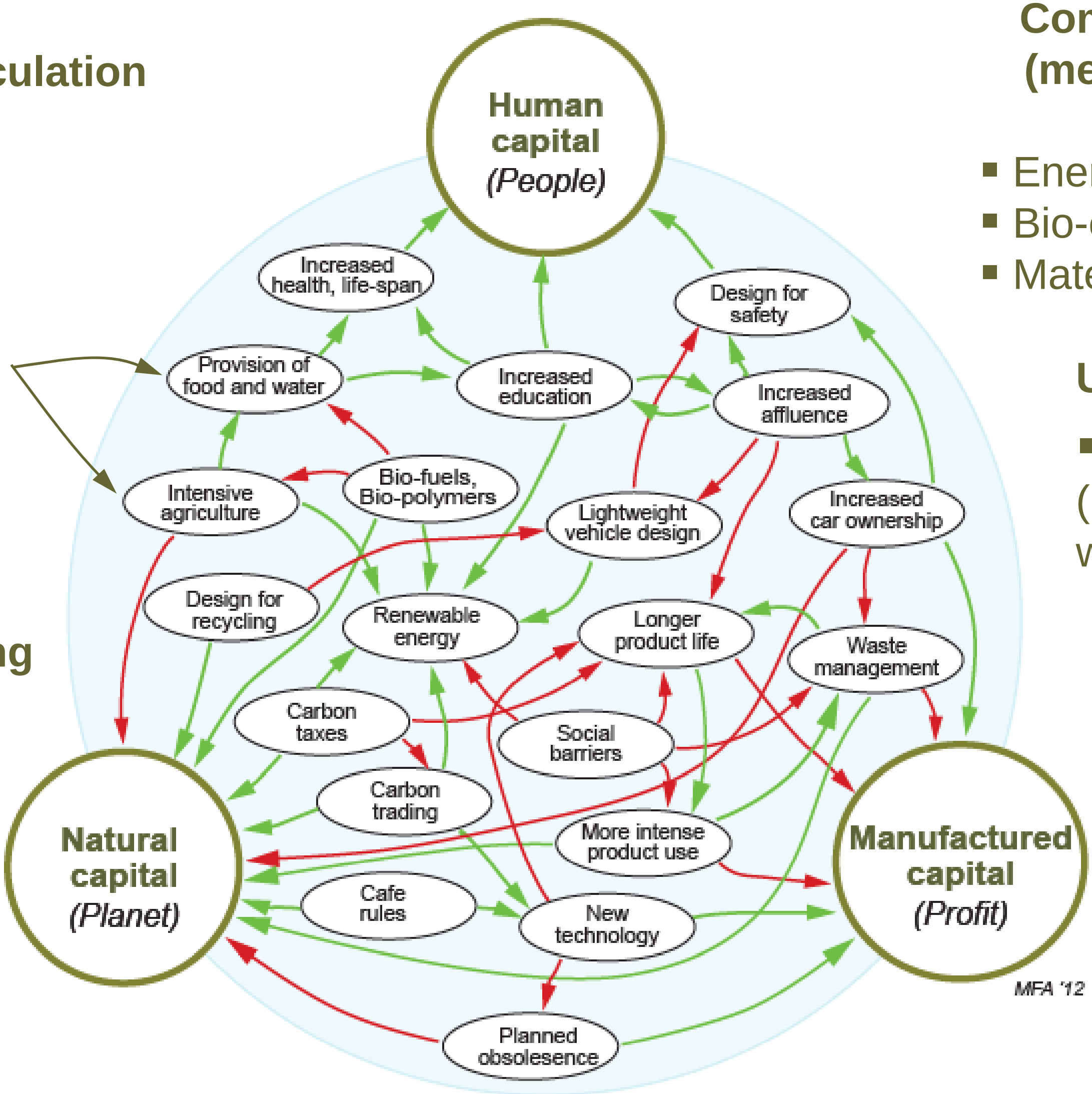
Many "single actions" ("articulations") of sustainable technology

Each is presented as *a* solution …but the articulations conflict

Motivation	Articulation	…….but
Reduce dependence on fossil fuels	Bio-fuels Bio-polymers	Competition with food production *(people)*
Stimulate low-carbon economy	Carbon taxes	Increase energy price *(profit)*
Stimulate circular materials economy	Design for recycling	Inhibits use of advanced materials
Social responsibility	Ethical sourcing	Increased resource costs

What is Sustainable Technology?

- No single articulation of sustainable technology
- Sustainable technology is an "Umbrella" term
- A collective of activities differing in spatial and temporal scale
- Conflicts – requires search for compromise

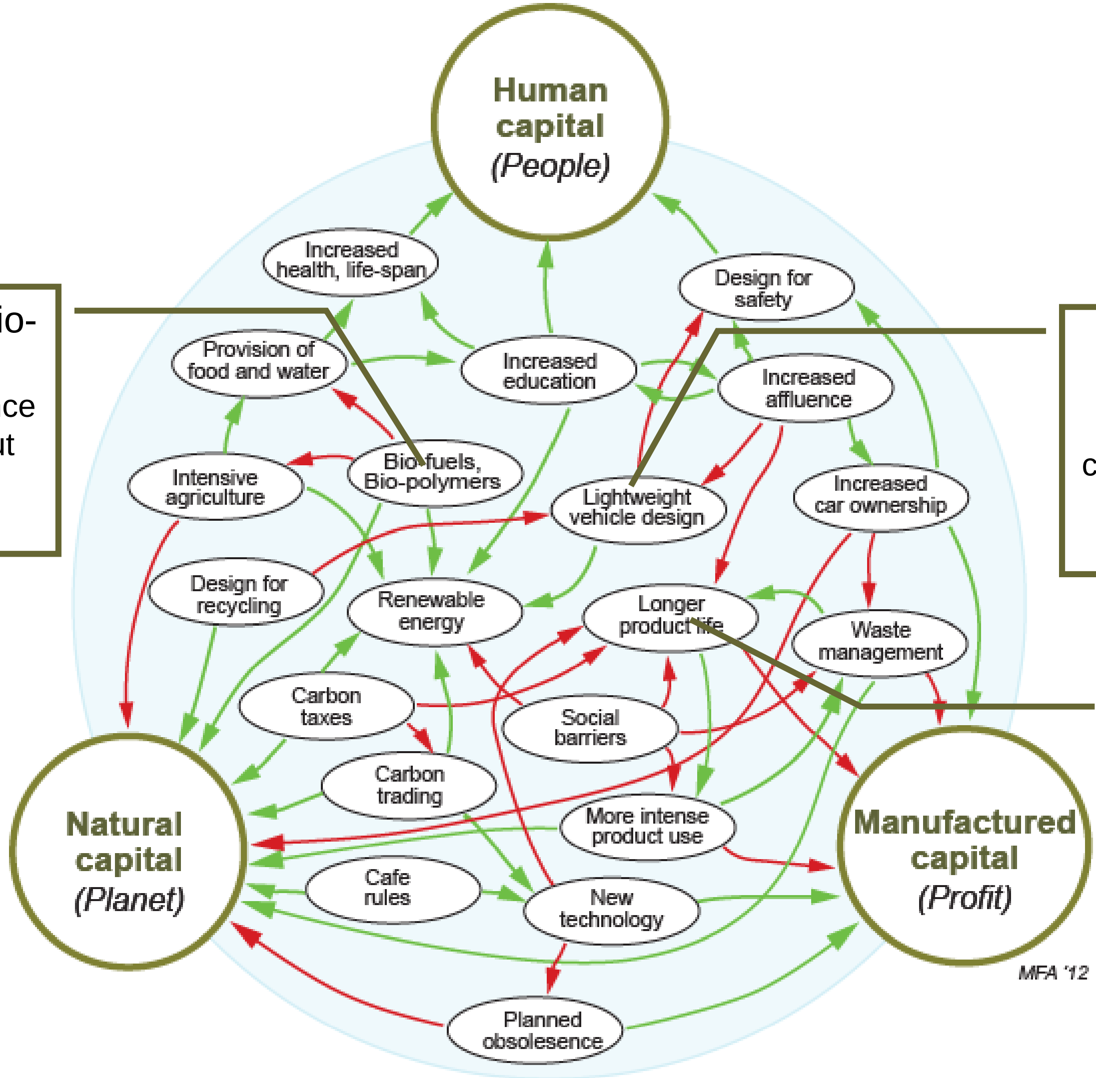


Common themes (meta-messages)
All rely on:
- Energy efficiency
- Bio-efficiency
- Material efficiency

Ultimate message:
- Provide same (more) functionality with less resources

What is Sustainable Technology?

Bio-fuels and bio-polymers – reduces dependence on fossil fuels, but compete with agriculture



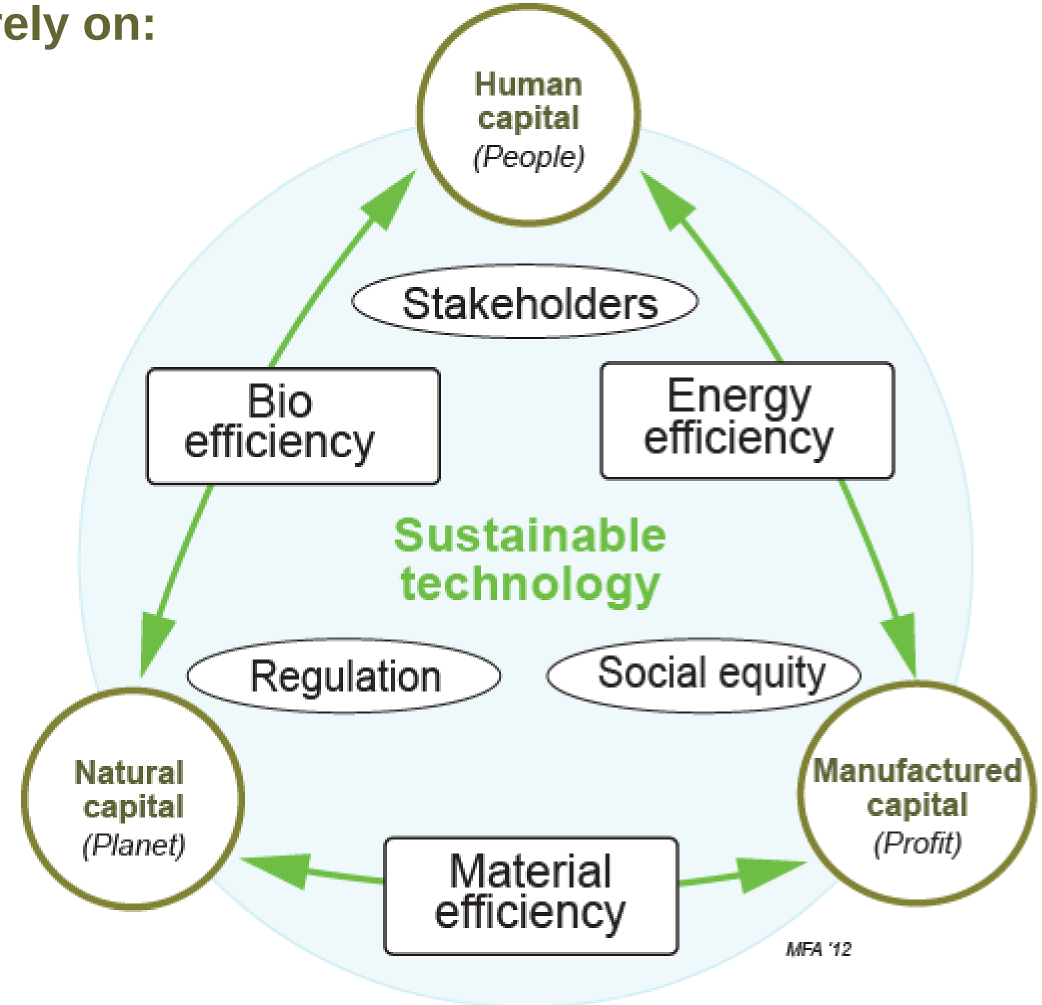
Light weight vehicle design – reduces fuel consumption but may preclude recycling

Longer product life – reduces material consumption, but may not be energy efficient.

Functionality with fewer resources

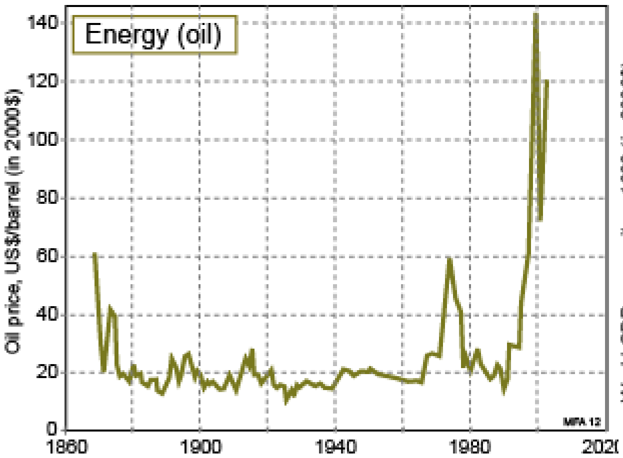
All three capitals rely on:

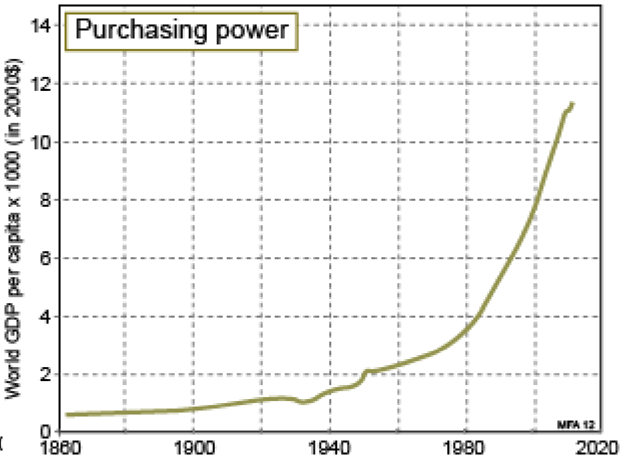
- **Energy efficiency**
- **Bio-efficiency**
- **Material efficiency**



Essential efficiencies

- **Energy efficiency –** widely practiced – **Energy = Money** in any language
- **Bio efficiency –** Agronomy (scientific agriculture) widely practiced
- **Material efficiency is neglected – Why?** Relative cost of material and labour





- **The ratio is changing. Material efficiency now matters**

Economically (profit)

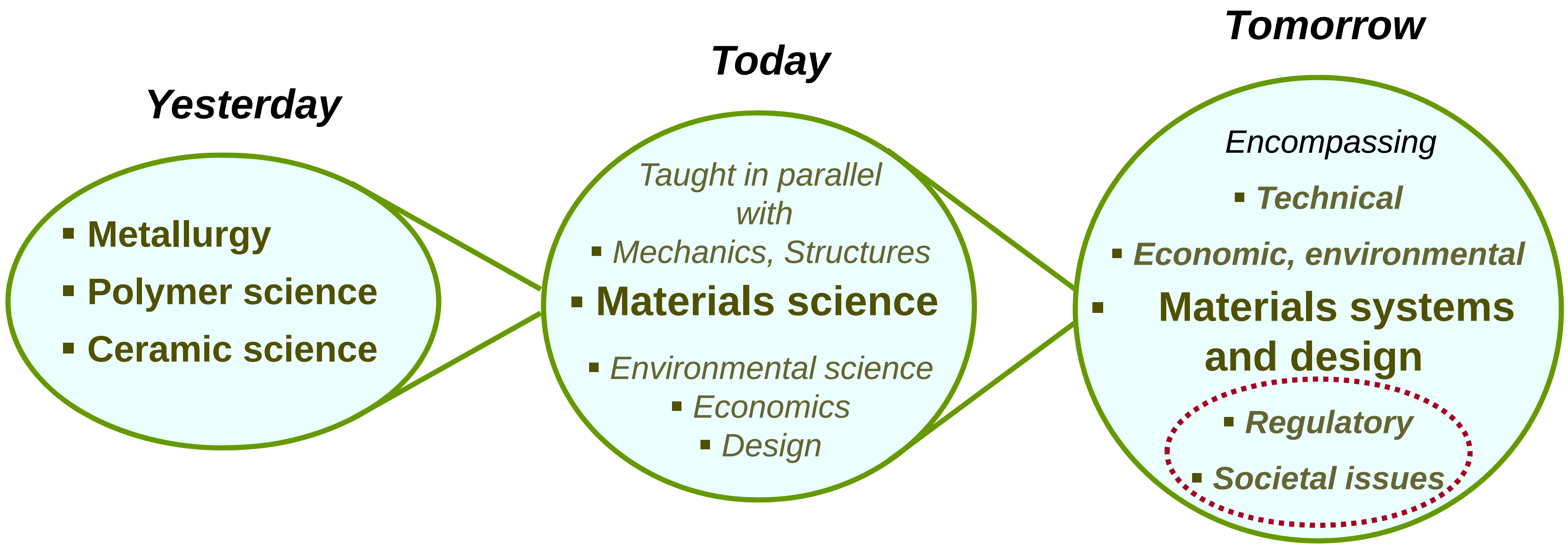
Environmentally (pollution)

Sustainably (resource depletion)

SUSTAIN: a database to support sustainable technology

- **Material efficiency** essential to provide needs of present and of future generation
- **Select materials** to maximize functionality with minimum material loss
- **Boundary conditions:** regulations, incentives, voluntary obligations
  social equity, ethical sourcing
- Provide a **tool** to help with this

The evolution of Materials teaching



The need:

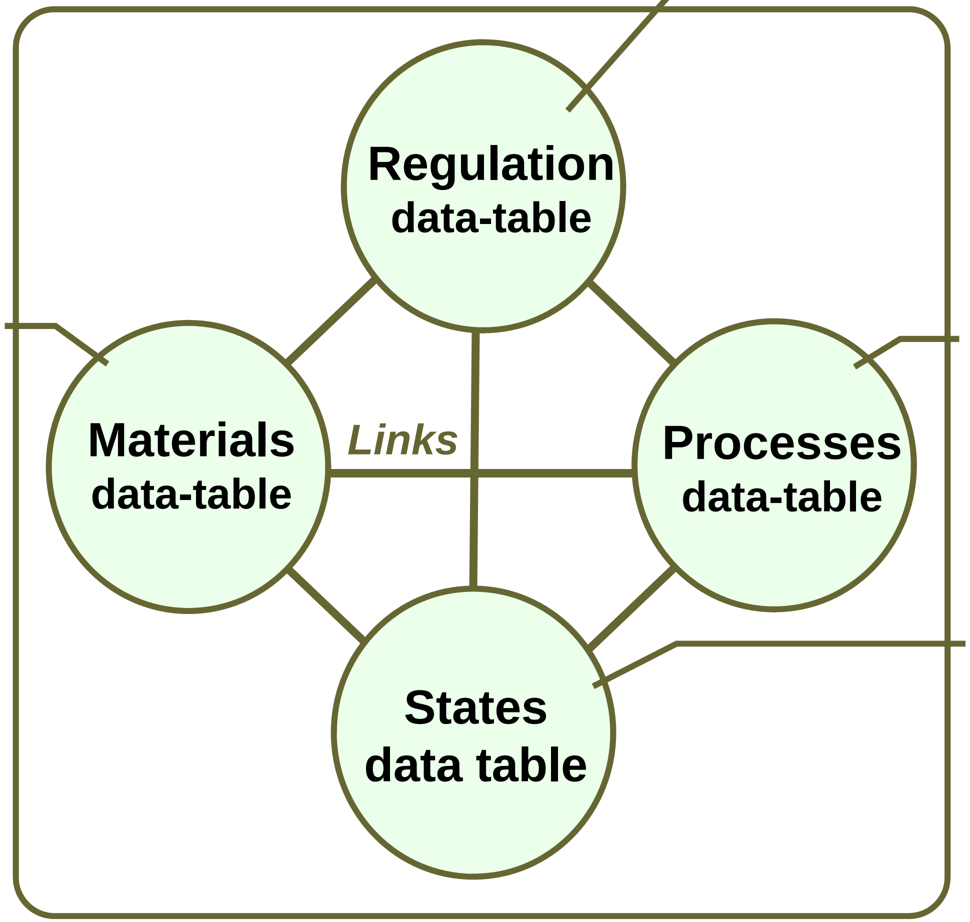
A data source that allows material selection technical grounds

And helps with pointers to regulation and societal issues

Organizing information: the CES EduPack SUSTAIN DB

The database

Data for
- *Metals & alloys*
- *Polymers*
- *Ceramics & glasses*
- *Hybrids*



Data for
- *Standards*
- *EU directives*
- *US regulation*
- *Tax legislation*
- *Critical materials*

Data for
- *Joining*
- *Shaping*
- *Surface treatment*

Data for
- *Geography*
- *People*
- *Human rights*
- *Economy*
- *Energy*
- *Military spend*

of the world's states

The Regulation data-table - typical record

End-of-Life Vehicles (ELV)

Relevant sector

Automobile industry. (European Union Directive requiring take back and recycling of vehicles at end of life.)

Summary of legislation

End-of-Life Vehicles (ELV, 2000). The European Community Directive, EC2000/53, establishes norms for recovering materials from dead cars. The initial target, a rate of reuse and recycling of 80% by weight of the vehicle and the safe disposal of hazardous materials, was established in 2006. By 2015 the target is a limit of 5% by weight to landfill and a recycling target of 85%. The motive is to encourage manufacturers to redesign their products to avoid using hazardous materials and to maximise ease of recovery and reuse.

Reference

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http://rod.eionet.europa.eu/instruments/526

The States data-table - typical record

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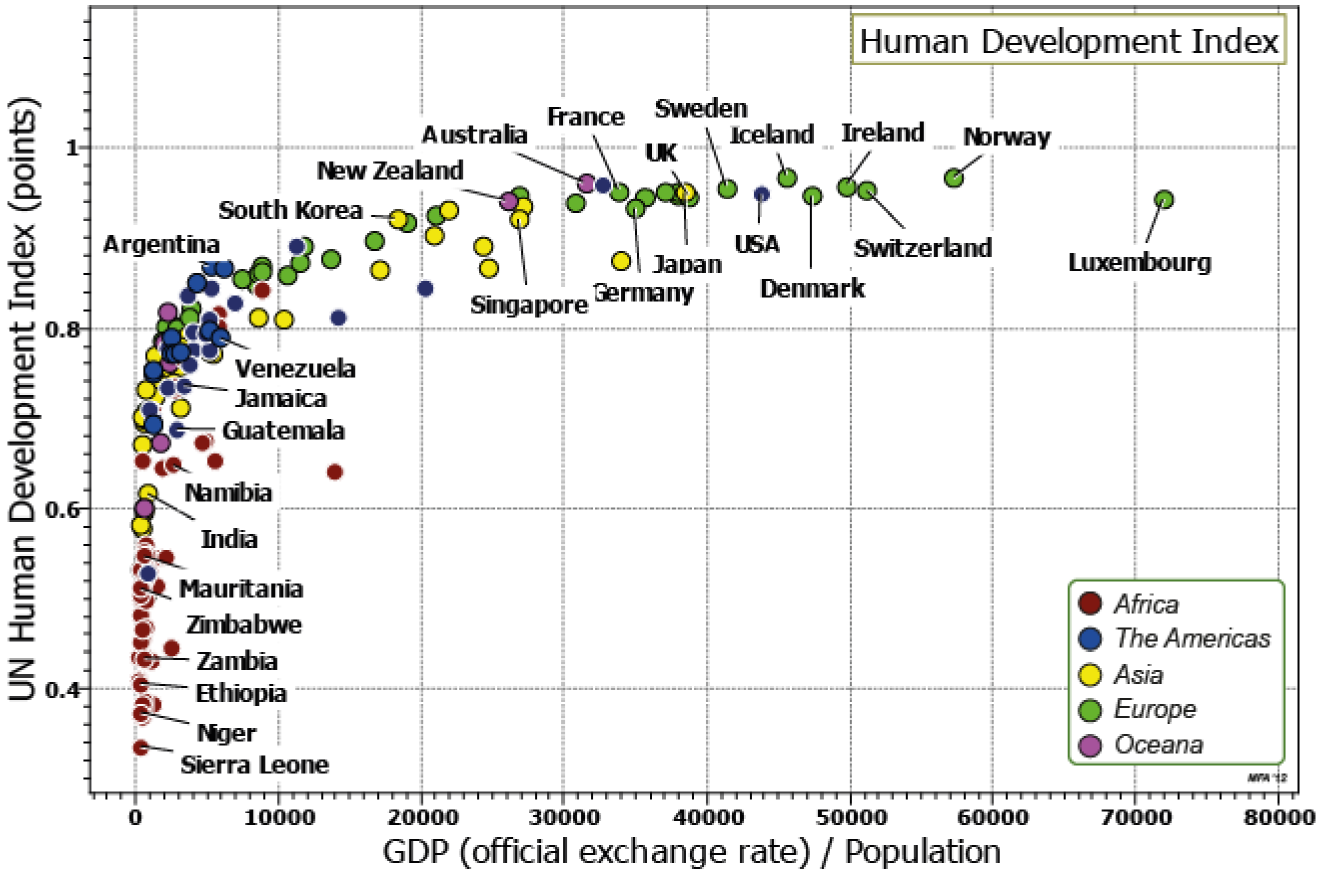
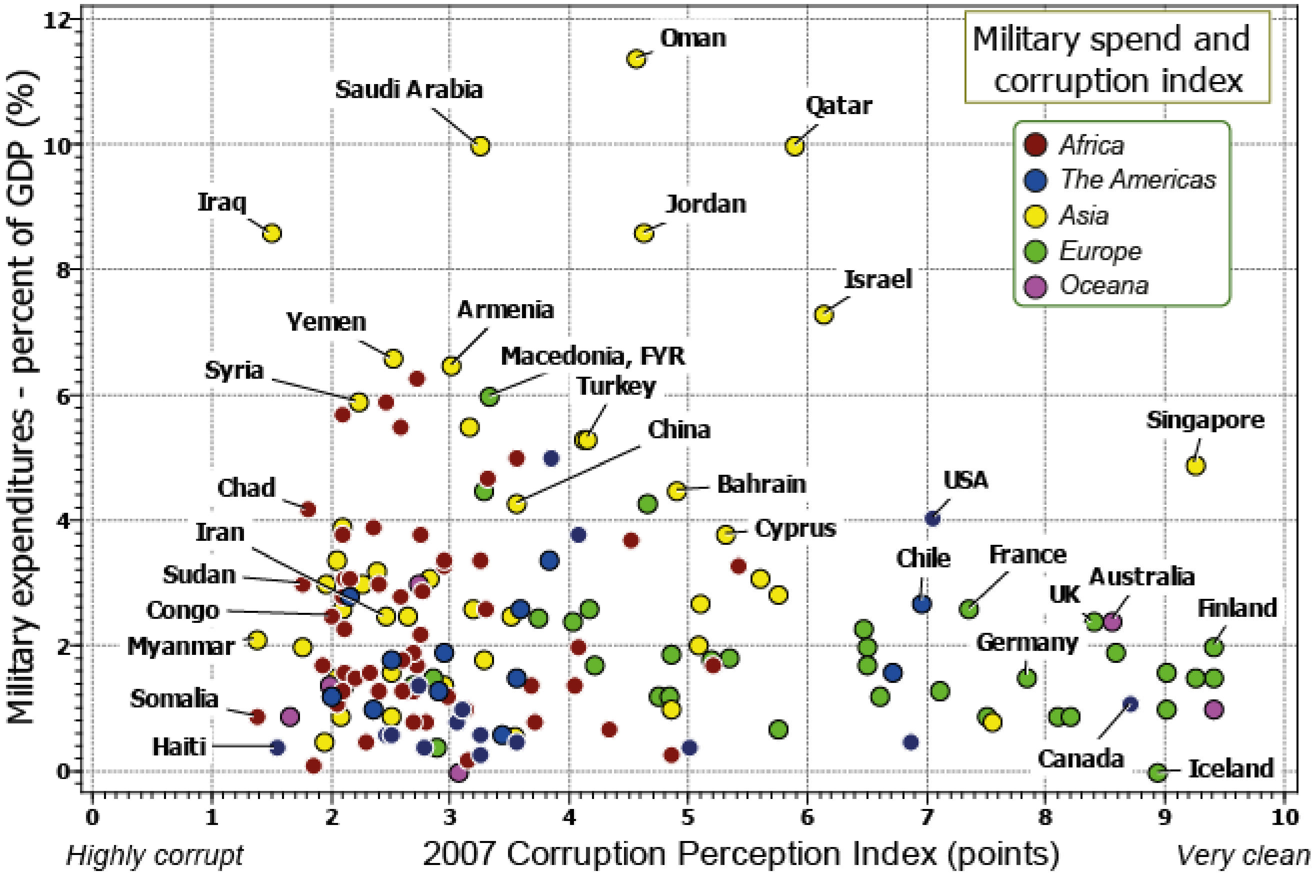
France

Geography		
Area (Land Only)	6.4e5	km^2
People		
Population	6.37e7	
Median Age	39	yrs
Satisfaction with life scale (SWLS)	220	points
Human Rights & Corruption		
Death Penalty	Abolished	
2007 Corruption Perception Index	6.9 - 7.8	points
Economy & Development		
GDP (official exchange rate)	2.15e12	USD
UN Human Development Index	0.95	points
Energy and carbon		
Electricity consumption	4.52e11kWh	
Oil consumption	1.97e6	bbl/day
Annual Greenhouse Gas Emission	4.17e8	Tonnes $CO_{2\ eqiv}$/year
Military		
Military expenditures - percent of GDP	2.6	% of GDP

UN Development index and GDP



Ethical sourcing



Material efficiency: the wind turbine

Materials

Material selection

- Blades
- Generator
- Support structure
- Grid connection

Design

Engineering design

- Aerodynamic efficiency
- Electrical efficiency
- Durability

Regulation

- Kyoto protocol etc.
- Renewable obligations
- Renewable subsidies
- Planning permission
- Material supply chain issues

Economic instruments

Society

- Economic concerns
- Technical concerns
- Environmental / Aesthetic concerns
- Social/cultural concerns
- Geopolitical issues

Stakeholder acceptance

Wind turbine – notional poster

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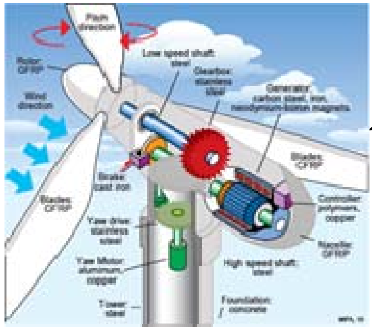
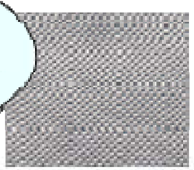
Materials



Blades
- Wood
- E-glass - PVC
- E-glass - epoxy
- Carbon - epoxy

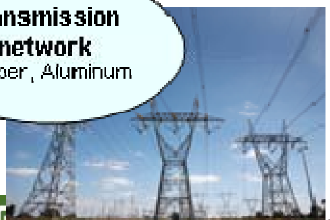


Generator
- Nd-Fe-B magnets

(Critical materials)

Enclosure and support
- GFRP, steel, concrete

Transmission network
- Copper, Aluminum

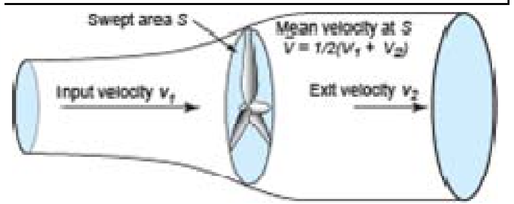


Design

When wind comes into contact with the rotor of a wind turbine, some of its kinetic energy is imparted to the blades, driving their rotation. This rotation is transmitted through a gearbox to a generator, creating electric power. Wind speed v increases with height h above ground level:

$$v(h) \approx v_{10}\left(\frac{h}{10}\right)^{0.14}$$

where v_{10} is the wind speed at a height $h = 10m$.



The peak power of a turbine (the Betz limit) varies as the swept area S times the cube of the incoming wind speed v_1 $Power = 0.3\ \rho\ S\ v_1^3$ ..

(ρ is the density of air).

The tip speed ratio is the ratio of the blade tip speed and the speed of the wind. High efficiency 3-blade-turbines have tip-speed ratios of 6 to 7. Composite blades gives low rotational inertia so the turbine accelerates quickly if the winds change, keeping the tip speed ratio constant. The lighter blades reduce gravitational fatigue loading.

Regulations, incentives

Kyoto Protocol

The Kyoto Protocol (1997) is an international treaty to reduce the emissions of gases that, through the greenhouse effect, cause climate change.

Carbon commitment

The UK is committed to reducing its greenhouse gas emissions by at least 80% by 2050, relative to 1990 levels.

Renewable energy subsidies

Many countries offer a feed-in tariff that amounts to a subsidy for renewable energy..

Planning permission

Planning permission may require a public enquiry and can take years.

Stakeholder acceptance

Government

Wind power contributes to carbon commitment

Energy providers

Subsidised wind power is profitable for energy companies

Energy consumers

Clean energy. But expensive

Anti wind lobby

Citizen's groups opposed to wind turbines because of visual and acoustic intrusion.

Nature conservancy groups

Groups with mission to conserve habitat, bio-diversity, countryside

Ethical sourcing

Civil rights
Gender equity
Child protection

So What?

- **Sustainability is here to stay and will affect all engineering practices**
- **There is a growing demand for Materials efficiency and it will be part of decision-making**
- **Designers need to understand the socio-economic dimensions of their decisions**

Granta Design is currently working on a database and other resources to aid the teaching of this topic. We are always interested in hearing from CES EduPack users with good ideas and data sources. You can submit these using the Submit Feature Request button in the CES EduPack.

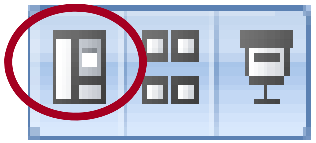
Lecture Unit Series

These PowerPoint lecture-units are on the Teaching Resource Website

Topic	Number	Name
Finding and Displaying Information	Unit 1	**The materials and processes universe**: families, classes, members, attributes
	Unit 2	**Materials charts**: mapping the materials universe
Material Properties	Unit 3	**The Elements**: Property origins, trends and relationships
	Unit 4	**Manipulating Properties**: Chemistry, Microstructure, Architecture
	Unit 5	**Designing New Materials**: Filling the boundaries of materials property space
Selection	Unit 6	**Translation, Screening, Documentation**: the first step in optimized selection
	Unit 7	**Ranking**: refining the choice
	Unit 8	**Objectives in conflict**: trade-off methods and penalty functions
	Unit 9	**Material and shape**
	Unit 10	**Selecting processes**: shaping, joining and surface treatment
	Unit 11	**The economics**: cost modelling for selection

Topic	Number	Name
Sustainability	Unit 12	**Eco Selection**: the eco audit tool
	Unit 13	**Advanced Eco design**: systematic material selection
	Unit 14	**Low Carbon Power:** Resource Intensities and Materials Use
Special Topics	Unit 15	**Architecture and the Built Environment**: materials for construction
	Unit 16	**Structural sections**: shape in action
	Unit 17	**CES EduPack Bio Edition:** Natural and man-made implantable materials
	Unit 18	**Materials in Industrial design**: Why do consumers buy products?
Advanced Teaching and Research	Unit 19	**Advanced Databases:** Level 3 Standard, Aerospace and Polymer
	Unit 20	**Hybrid Synthesizer:** Modelling Composites, Cellular structures and Sandwich panels
	Unit 21	**Database creation:** Using CES Constructor in Research
	Unit 22	**Research:** CES Selector and Constructor
	Unit 23	**Campus:** Overview of this commercial polymers database

Each frame of each unit has explanatory notes. You see them by opening the PowerPoint slide in Notes view (View – Notes pages) or by clicking this icon in the bottom toolbar of PowerPoint



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Accuracy

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- Recorded webinars
- Posters
- White Papers
- Solution Manuals
- Interactive Case Studies

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TEACHING RESOURCES

Materials and Sustainable Development

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Didac Ferrer
Jennifer Bruce

Department of Engineering
University of Cambridge,
Granta Design, Cambridge and
Universitat politecnica de Catalunya

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Fuel efficient, but sustainable?

Safe, but sustainable?

- *Energy*
- *Materials*
- *Environment*
- *Emissions*
- *Safety*
- *Legality*
- *Social acceptance*
- *Space*
- *Economics*

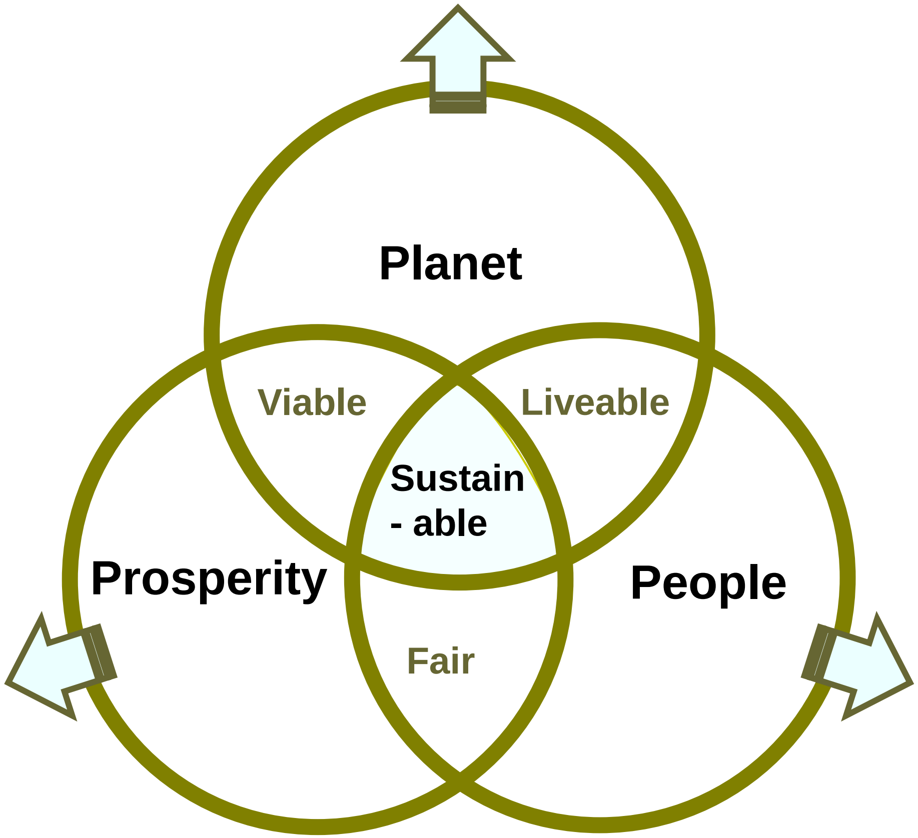
Defining "Sustainable development"

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

Report of the Brundtland commission of the UN, 1987

- ***But how?***
- ***And where do materials fit in?***
- ***"Sustainability" vs. "Sustainable development"***

Business view: Triple Bottom Line accounting



Report

- *Financial bottom line*
- *Social / ethical performance*
- *Environmental performance*

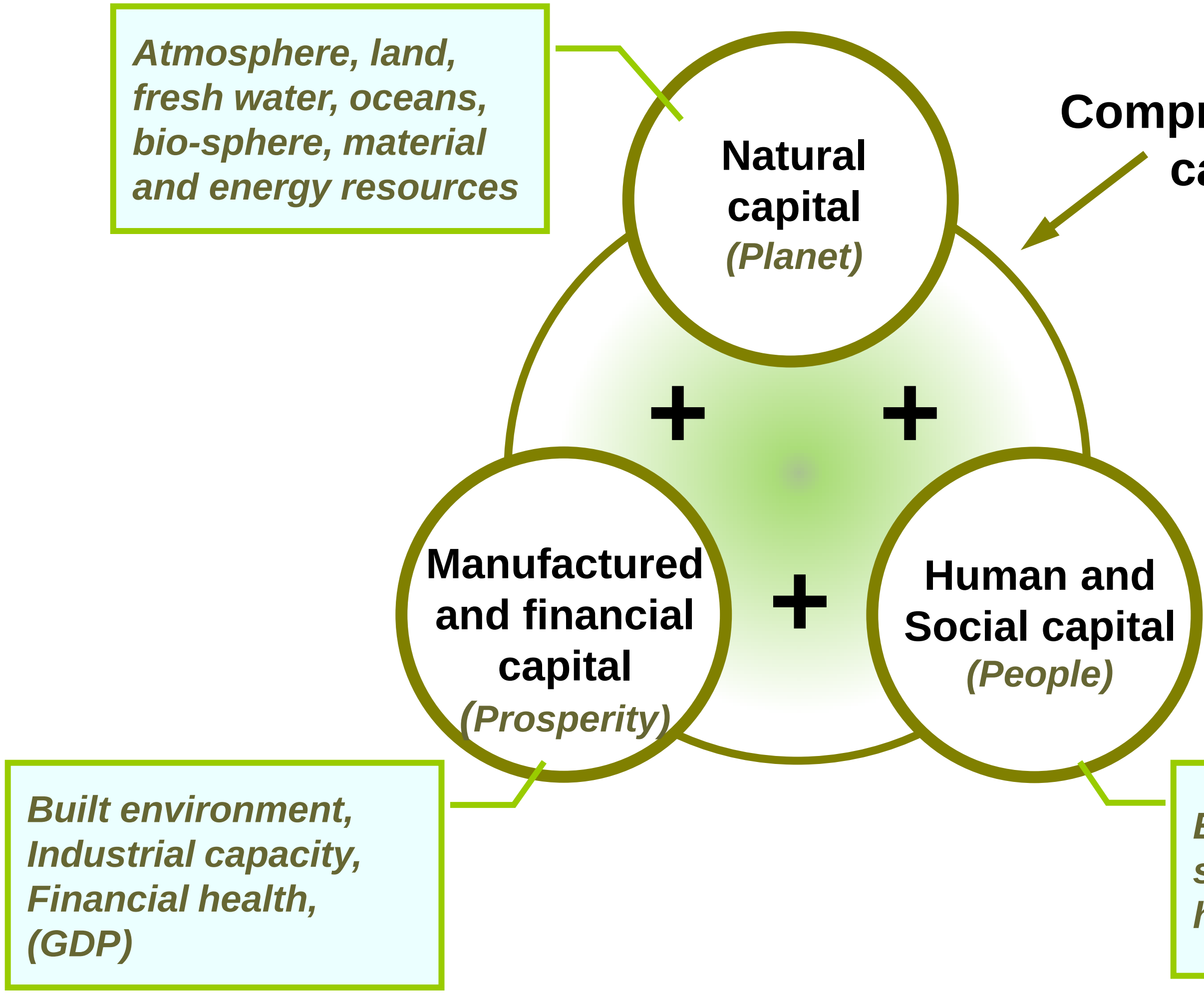
- *Dow Jones Sustainability Index*

- *But what can a designer do?*

- *Decouple the circles*

  – unpack their meaning

Macro-economic view: the Three Capitals



- *Sustainable development = Growth in Comprehensive capital*
  - *How link to research on Sustainable Development?*

Articulations of sustainable development

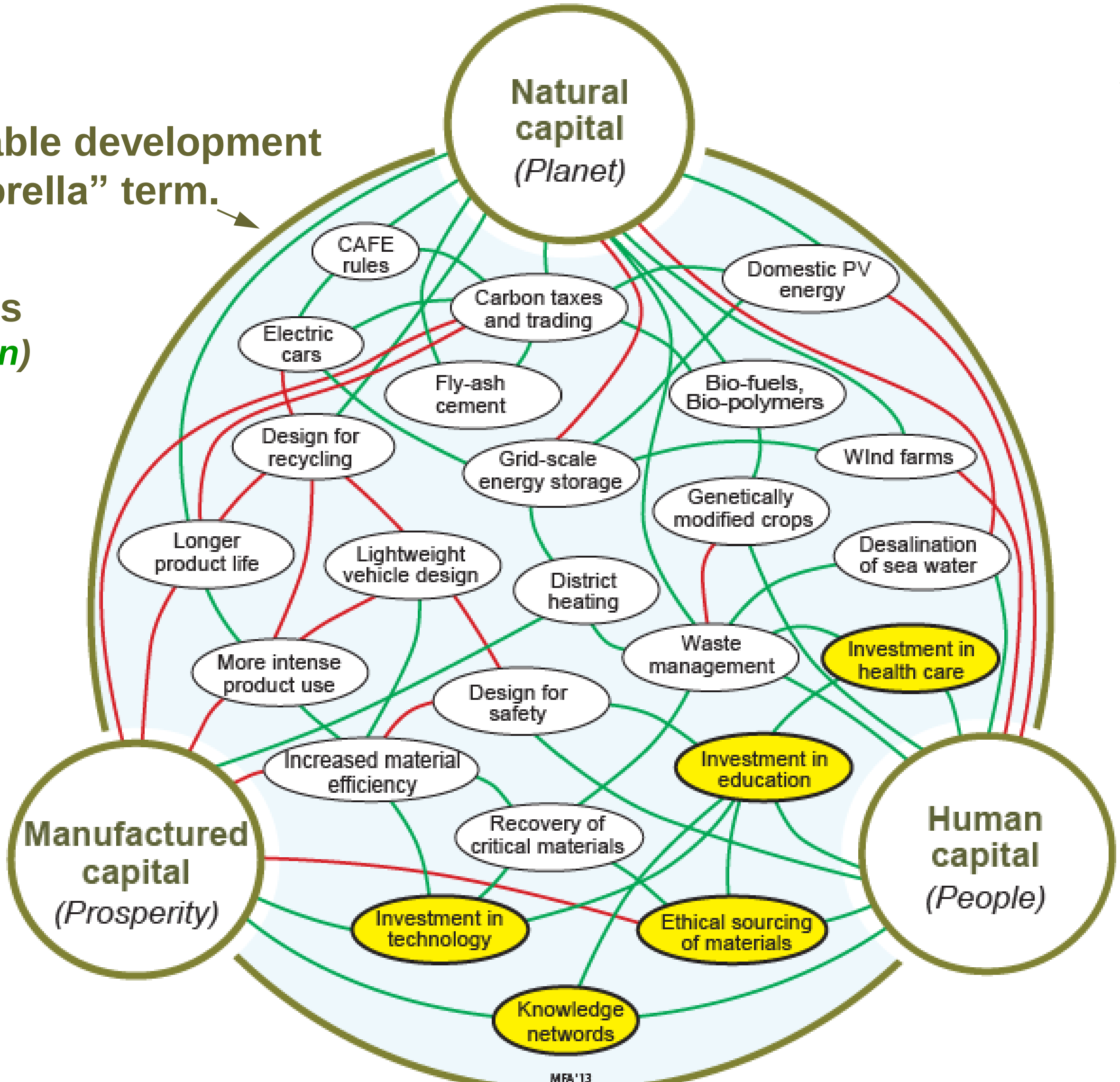
Many single actions ("articulations") claim to support sustainable development

Motivation *(Prime objective)*		**Articulation**		**Unintended consequence**
Reduce dependence on oil, gas, coal	←	**Bio-fuels Bio-polymers**	→	*Competition with food production (People)*
Stimulate low-carbon economy	←	**Carbon taxes**	→	Increase energy price *(Prosperity)*
Stimulate circular materials economy	←	**Mandatory recycling**	→	Inhibits use of advanced materials *(Planet)*

Each articulation has a **Prime Objective** with a { **physical scale** / **time scale** }

Map of Articulations

- **Sustainable development is an "Umbrella" term.**
- **Conflicts** ***(red, green)***



What can we distil from this picture? Group under:

- **Materials**
- **Design**
- **Environment**
- **Regulation**
- **Society**
- **Economics**

Analysing an “articulation”

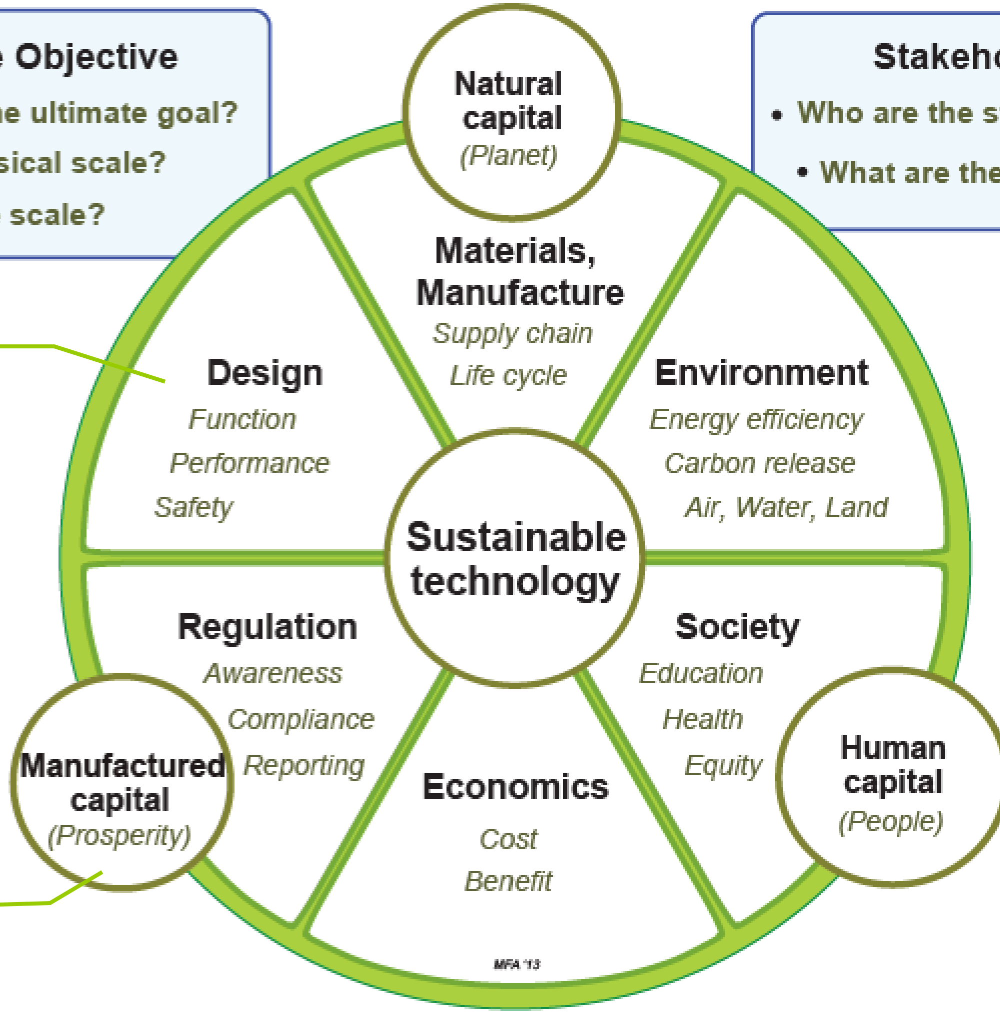
Prime Objective

- What is the ultimate goal?
- What physical scale?
- What time scale?

Stakeholders

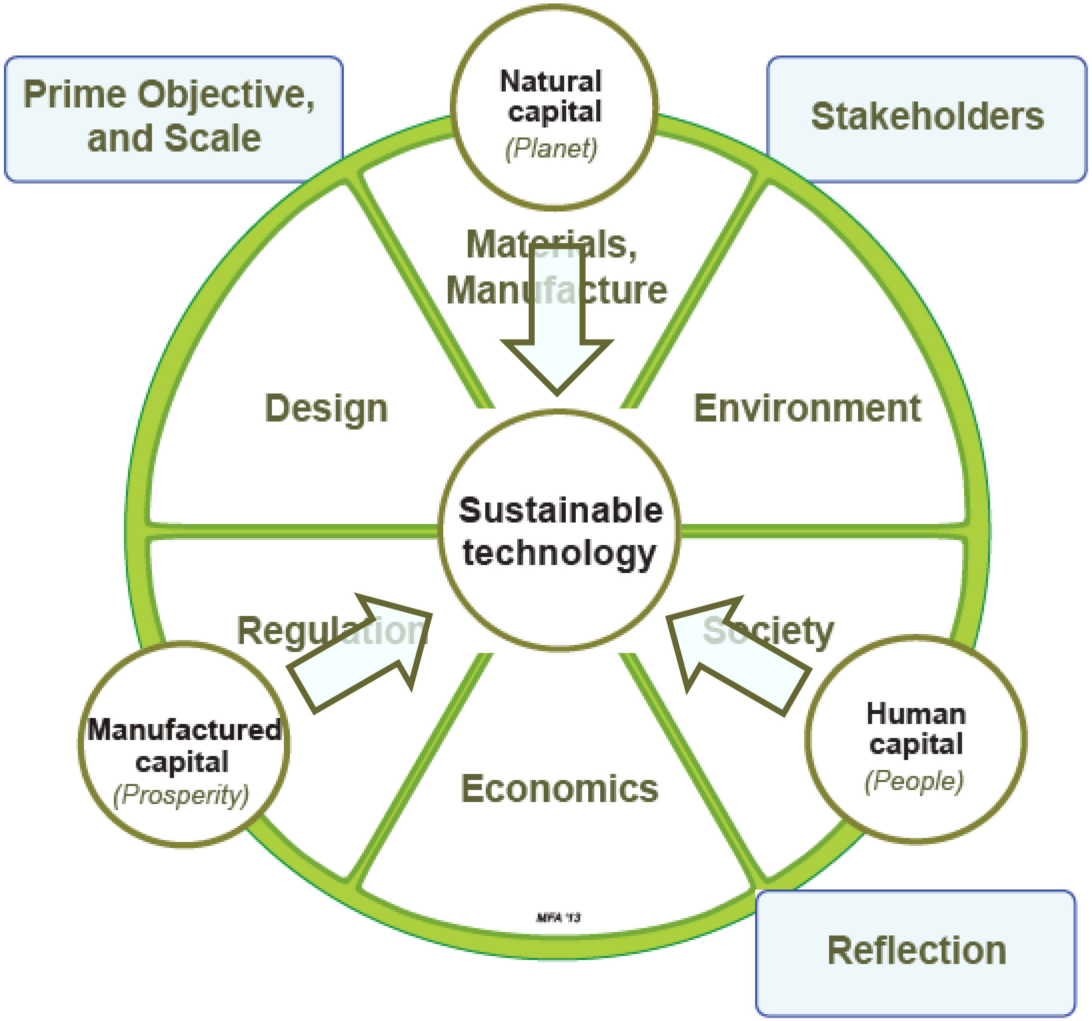
- Who are the stakeholders?
- What are their concerns?

Factual questions – research systematically



Impact on capitals a matter for debate

Sustainable assessment: the method



Step 1: Clarify Objective

Step 2: Stakeholders

Step 3: Fact finding
- *objective*

Step 4: Integration
- *subjective*

Step 5: Reflection

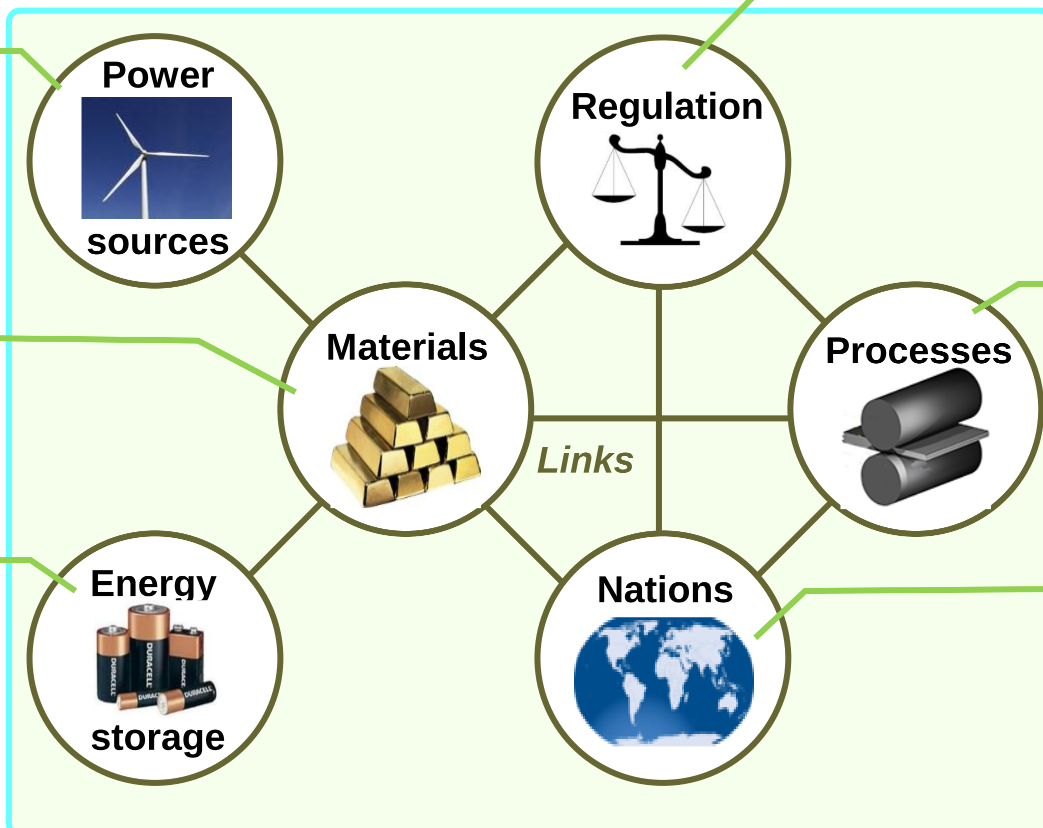
The CES EduPack SUSTAINABILITY DB

The SUSTAINABILITY database

Data for
- *Conventional*
- *Nuclear*
- *Renewable*

Data for
- *Metals*
- *Polymers*
- *Ceramics*
- *Hybrids*

Data for
- *Chemical*
- *Kinetic energy*
- *Pot. energy*
- *Elec. energy*

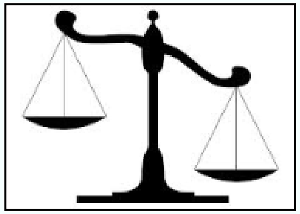


Information on
- *Standards*
- *EU directives*
- *US regulation*
- *Tax legislation*
- *Trading schemes*

Data for
- *Joining*
- *Shaping*
- *Surface treatment*

Data for Nations
- *Geography*
- *People*
- *Governance*
- *Human rights*
- *Economy*
- *Eco-footprint*

Regulation



End-of-Life Vehicles (ELV)

Relevant sector

Automobile industry.

Summary of legislation

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http://rod.eionet.europa.eu/instruments/526

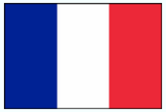
Nations of the World

Nations

Human Capital

Manufact'd Capital

Natural Capital



France

Geography

Area (Land Only)	6.4 e5	km^2

People

Population	6.4 e7	
Median Age	39	yrs
Satisfaction with life	220	points

Human Rights & Education

Press freedom index	0.13
Rule of Law index	91
Public spend on education, % GDP	5.6%

Economy & Development

GDP per capita	21,000	USD
Life expectancy	81.5	yrs
UN Human Development Index	0.95	points

Environment, energy and carbon

Ecological footprint	4.9	Global hectares (gha)
Oil consumption	1.9 e6	bbl/day
Annual Greenhouse Gas Emission	4.2 e8	Tonnes $CO_{2\ eqiv}$/year

The electric car – Prime objective

15 % of global fossil fuel CO_2 release comes from cars

Europe: Carbon Reduction Commitments (CRCs)
60 – 80 % reductions in carbon emissions by 2050

70 % of oil production is used for transport

President Obama aims to put one million electric vehicles on the road by 2015 to reduce US dependence on oil

State of the Union Address, 2011

Prime objective and scale →

- ***Decarbonize road transport***
- ***16 million cars/year by 2020***

Stakeholders: scan the press

Press reports

"CO_2 emissions 0 g/km."

Advertisement for Nissan Leaf.
The Times, 24.02.13

"Bloomberg endorse parking spaces for E.V. charging"

The mayor says he wants New York City to be a "national leader" in electric vehicles.
New York Times 14.02.13.

"That Tesla data: what it says and what it doesn't"

A reporter discovers that the claimed range of electric cars is sometimes overstated.
New York Times 14.02.13

"Leaf stalls"

Nissan admits that customers hesitate because of price and range anxiety.
The Times 5.03.13

"Are electric cars bad for the environment?"

Norwegian academics argue that electric cars can be more polluting than claimed.
The Guardian 4.02.13

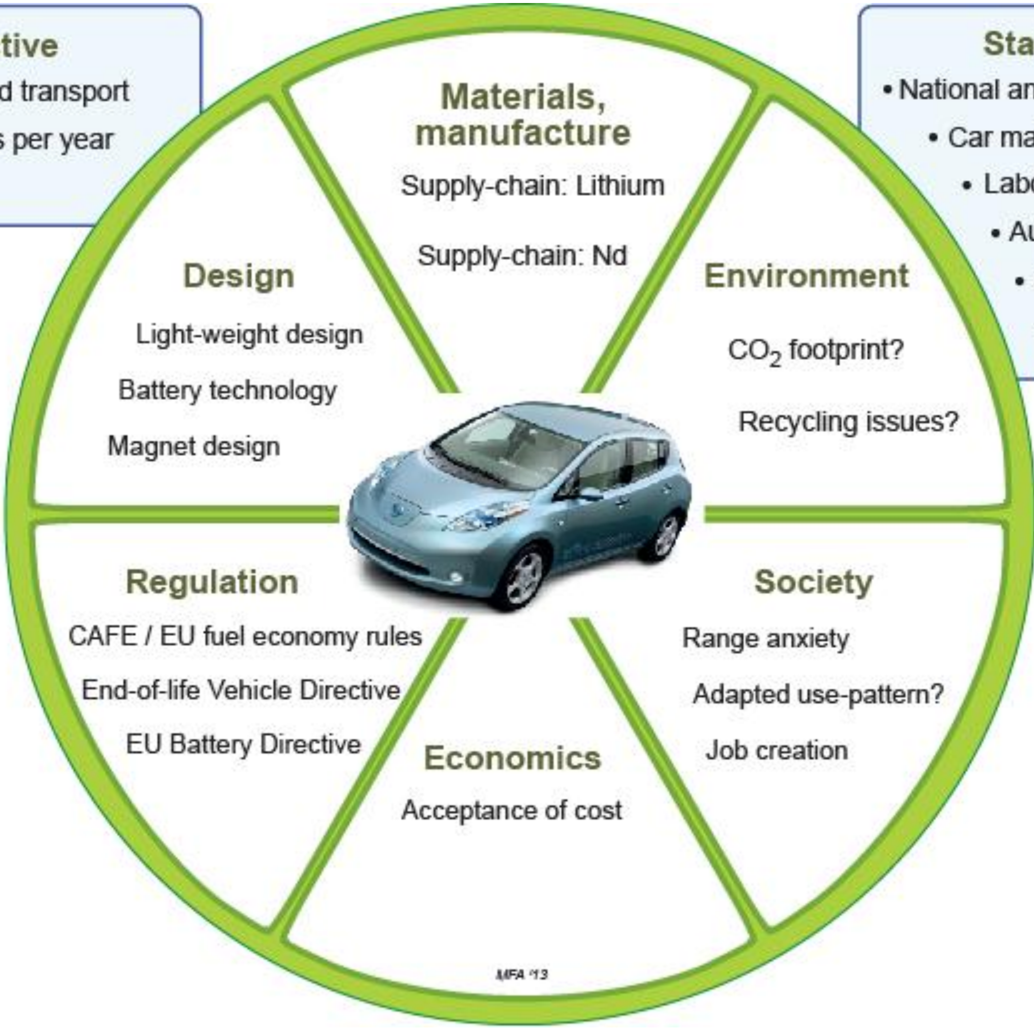
Electric cars: the first three steps

Step 1

Prime Objective

- De-carbonize road transport
- 16 million vehicles per year
- By 2020

Step 3



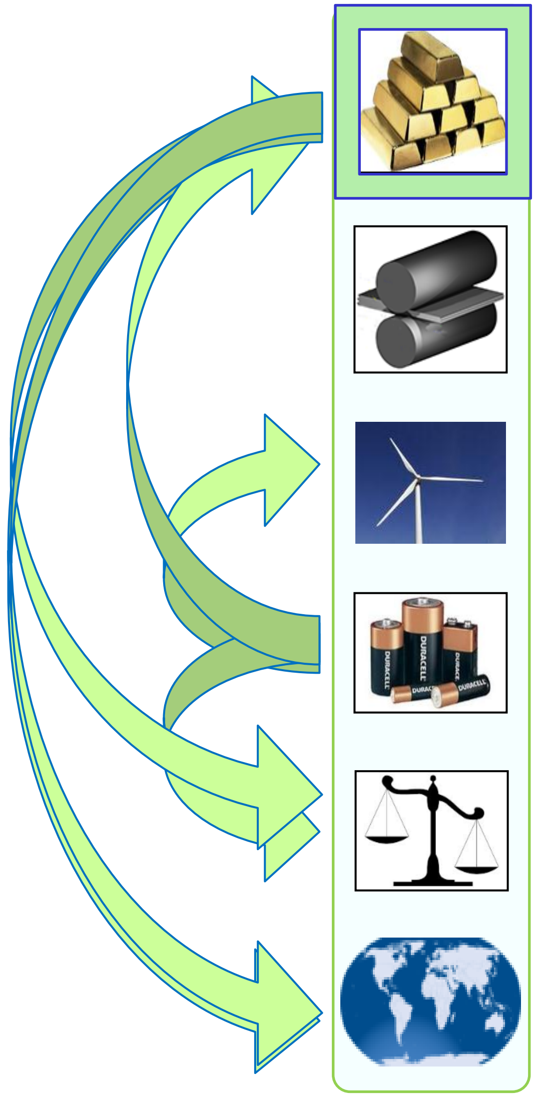
Step 2

Stakeholders

- National and Local Government
- Car makers and distributors
- Labor Unions
- Automobile Associations
- Green campaigners
- The driving public

Use of the database for fact-finding

Electric car



Six linked data-tables

Materials with source-nation

Processes

Power generation systems

Energy storage systems

Regulation and legislation

Nations: people, governance, human rights, economy, development

Materials (1)

Neodymium-boron magnet motors

Lithium-ion batteries

Bill of materials	kg
Carbon steel	790
Cast iron	151
Wrought aluminum (10% recycle)	30
Cast aluminum (35% recycle)	64
Copper / Brass	26
Magnesium	0.3
Glass	39
Thermoplastic polymers (PU, PVC)	94
Thermosetting polymers (Polyester)	55
Rubber	33
Platinum, exhaust catalyst	0.007
Electronics, emission control	0.27
Rare earth magnets (0.5 kg Neodymium)	**1.5**
Batteries (4.8 kg Lithium)	**100**
Total weight	1385

Nd-B magnets for motors

Lithium for lithium-ion batteries

Materials (2)

Material supply chain

16 million cars per year

- ***0.5 kg Neodymium per car***
- ***4.8 kg Li per car MINIMUM***

Neodymium

Producing Nation	Tonnes/year 2011
China	*22,100*
India	*510*
Brazil	*93*
Malaysia	*5*
World	**22,710**

***Nd** demand =*
***40%** present world production*

Lithium

Producing Nation	Tonnes/year 2011
Chile	*12,600*
Australia	*11,300*
China	*5,200*
Bolivia	*5,000*
Argentina	*3,200*
Portugal	*820*
Zimbabwe	*470*
Brazil	*160*
World	**34,000**

***Li** demand =*
***230%** present world production*

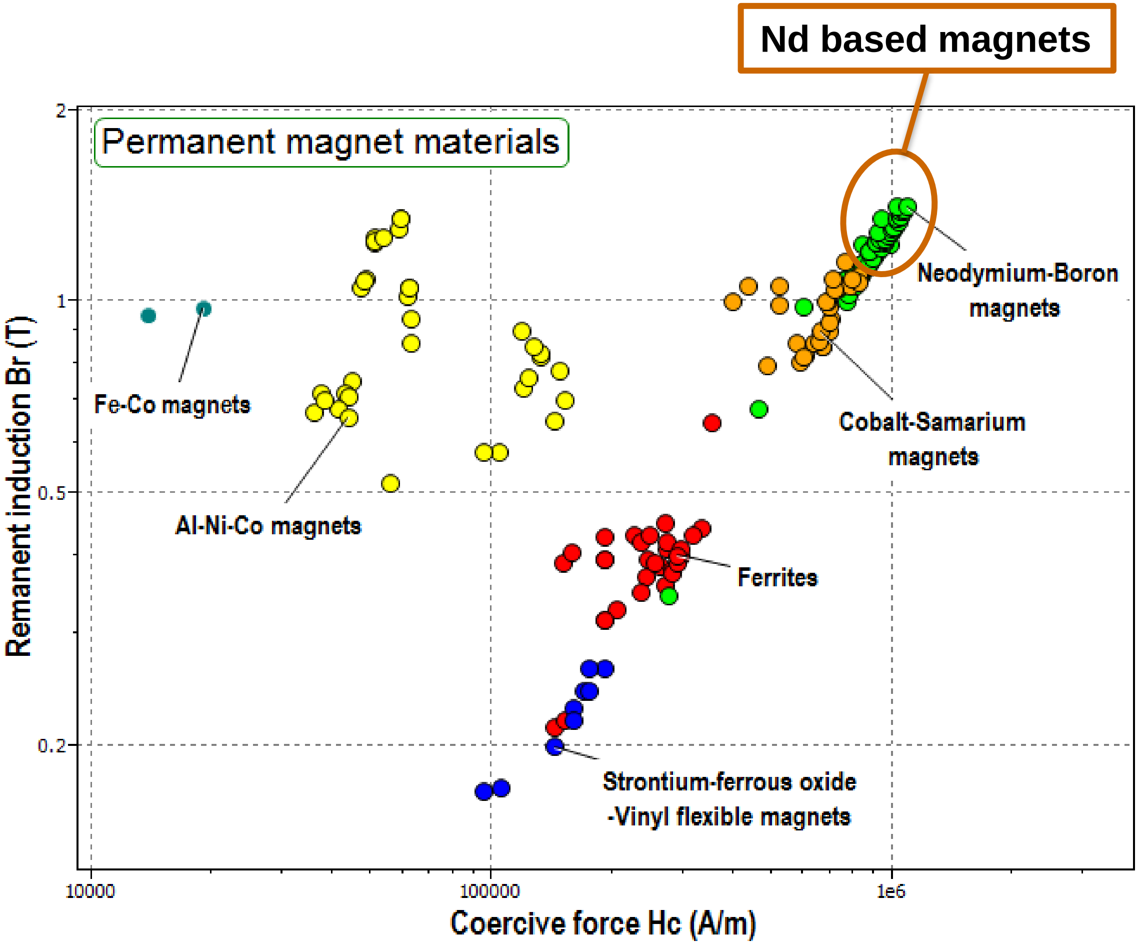
Facts

Materials

- ***Nd: Severe supply-chain concentration***
- ***Li: Current world production inadequate***

Alternative magnets?

Need high remanence and high coercive force



Facts

Design

- ***No better magnet than Nd-B***

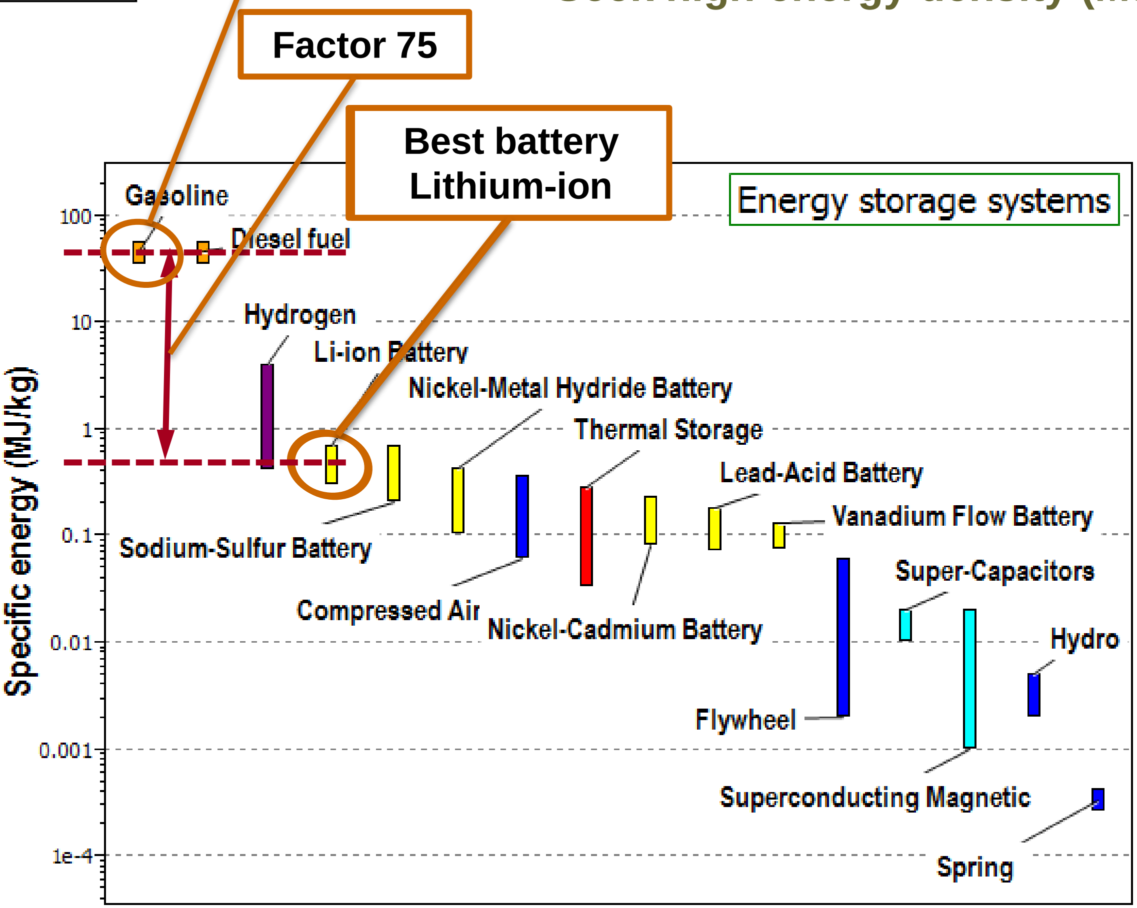
Materials

- *Nd, Li: Supply-chain issues*

Design (2)

Alternative batteries?

Seek high energy density (MJ/kg)



Facts

Design

- ***Energy density of batteries << gasoline***

- *No better magnet than Nd-B*

Materials

- *Nd, Li: Supply-chain issues*

Legislation and commitments

- Corporate fleet fuel-economy penalties –
  Fleet mileage > 35 mpg
- EU Battery Directive –
  None to landfill
- Plug-in electric vehicle subsidy –

USA				*$ 7,500*
China	*¥ 60,000*	–		*$ 9,700*
UK	*£ 5000*	–		*$ 7,000*
France	*€ 7000*	–		*$ 8,500*

Facts

Legislation

- ***Need recycle facilities for Nd and Li***

Design

- ***E-density of battery << gas***
- ***No better magnets than Nd-B***

Materials

- ***Nd, Li: Supply-chain issues***

Range and Cost anxiety

Energy density of energy-source

- Li-ion battery: ≈ 0.6 MJ / kg
- Conversion efficiency to axel ≈ 0.85

Energy required at axel

- Small car ≈ 0.5 MJ / km

Battery weight ≈ 1 kg per km of range

- 500 km range requires > half-tonne Li-ion battery
- Cost at todays prices $42,000

Facts

Society
- ***Range limited by battery weight and cost***

Legislation
- ***Must recycle Nd and Li***

Design
- ***E-density of battery << gas***
- ***No better magnets than Nd-B***

Materials
- ***Nd, Li: Supply-chain issues***

Environment

Decarbonize road transport

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

- CO_2 footprint, gas fired power ≈ 140 g / 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 / km**

Facts

Environment

- ***CO_2 footprint ≈ 100 g/km***

Society

- ***Range limited by battery weight and cost***

Legislation

- ***Need recycle facilities for Nd and Li***

Design

- ***E-density of battery << gas***
- ***No better magnets than Nd-B***

Materials

- ***Nd, Li: Supply-chain issues***

What have we got?

Step 1

Prime objective and scale

- Decarbonize road transport
- 20% of global production by 2020

Step 3 – Facts

Environment

- *CO_2 footprint ≈ 100 g/km*

Society

- *Range limited by battery weight and cost*

Legislation

- *Need recycle facilities for Nd and Li*

Design

- *E-density of battery << gas*
- *No better magnets than Nd-B*

Materials

- *Nd, Li: Supply-chain issues*

Step 2

Stakeholders

- National, local government
- Car makers and retailers
- Labor unions
- Green campaigners
- Automobile associations
- Car buying public

Step 4 – Integration

Students (in groups) debate impact on 3 capitals

Step 4 – Integration

Prime Objective

Stakeholders

Facts

Environment

- *CO_2 footprint ≈ 100 g/km*

Society

- *Range limited by battery weight and cost*

Legislation

- *Need recycle facilities for Nd and Li*

Design

- *E-density of batteries << gas*
- *Dependent on Nd-B magnets*

Materials

- *Nd, Li: Supply-chain issues*

Integration

Natural Capital

- **Prime objective -** *not met until grid decarbonized*

Manuf'td Capital

- **Missing infrastructure –** *Lithium, Neodymium production / recycling*
- **Subsidies** - *Poor use of taxes?*

Human Capital

- **Satisfaction?** *Expectations not (at present) met*

Step 5 – Reflection

Prime Objective

Stakeholders

Facts

Environment

- *CO_2 footprint ≈ 100 g/km*

Society

- *Range limited by battery weight and cost*

Legislation

- *Need recycle facilities for Nd and Li*

Design

- *E-density of batteries << gas*
- *Dependent on Nd-B magnets*

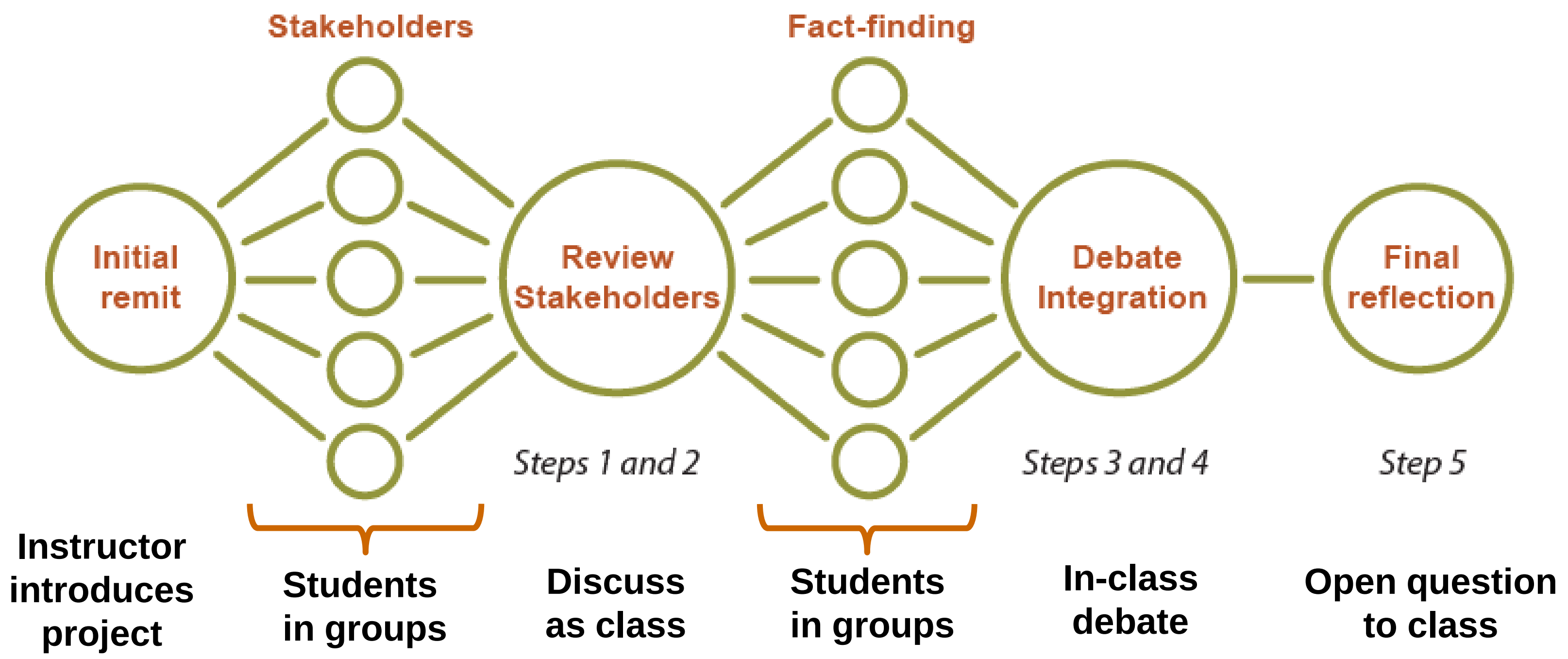
Materials

- *Nd, Li: Supply-chain issues*

Reflection

- **Short term – not sustainable**
- **Long term – rethink (redefine?) the way cars are used**
  – rethink use of electrical power for cars

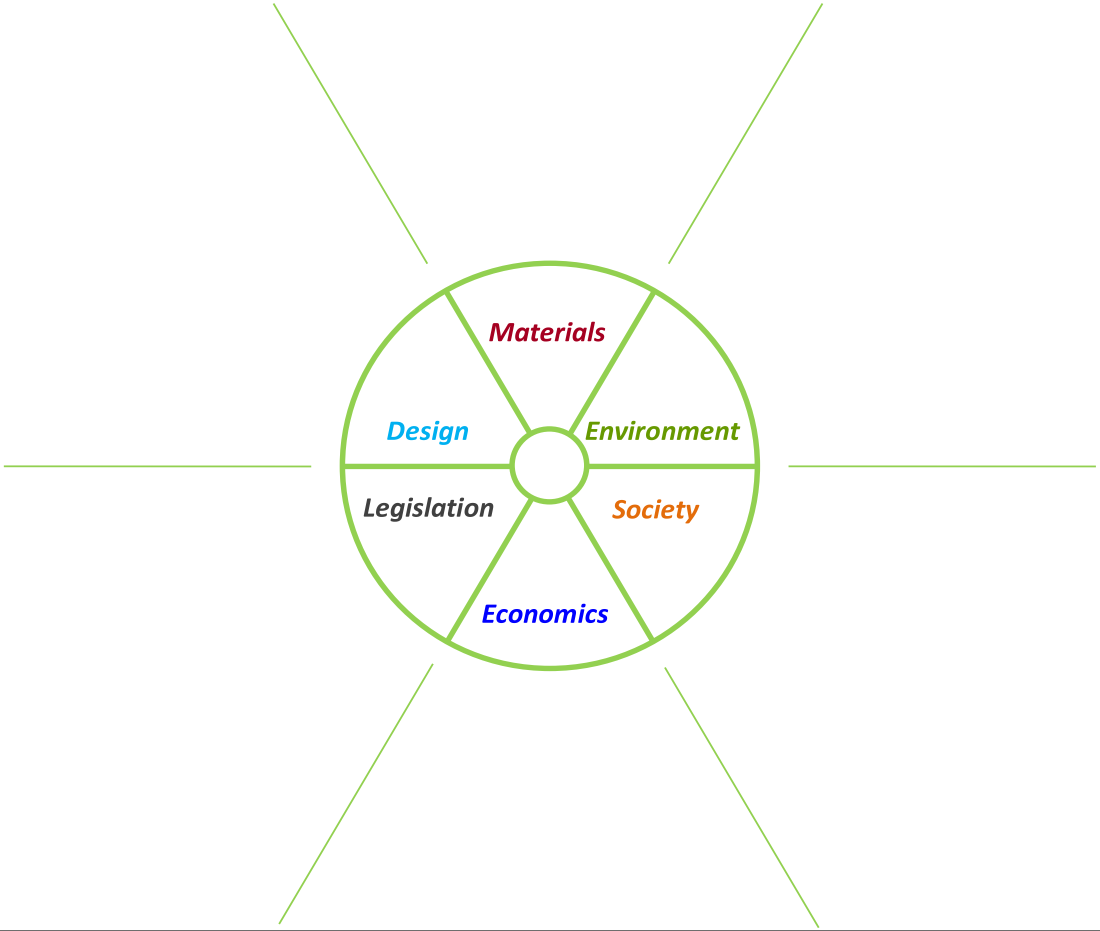
Running the project



Kick-off A3 Template

1. Prime Objective and Scale:

3. Fact - finding



2. Stakeholders

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This presentation is a brief summary of a student project, designed to be approachable to help students understand the 5-layer methodology outlined in the paper "Materials and Sustainability" (2014, M. F. Ashby and D. Ferrer)
http://teachingresources.grantadesign.com/Type/Papers/PAPSSDEN13

On Granta's Teaching Resources Website it is accompanied by student hand-outs and a sample, more detailed, analysis.

Michael F. Ashby, 2014
Department of Engineering, University of Cambridge, and Granta Design, Cambridge

Sustainable Development Projects

Project 1. Greener Beer Cans

Michael F. Ashby, 2014
Department of Engineering, University of Cambridge, and Granta Design, Cambridge

Step 1: Project, Prime objective and Scale

Background

- *Beneficial Brewery markets beer in 16 oz (473 ml) aluminum cans.*
- *Sales: 500 million cans per year.*
- *Eco-aware shareholders request switch to steel cans.*
- *Reasoning: steel has lower embodied energy and CO_2 than aluminum.*

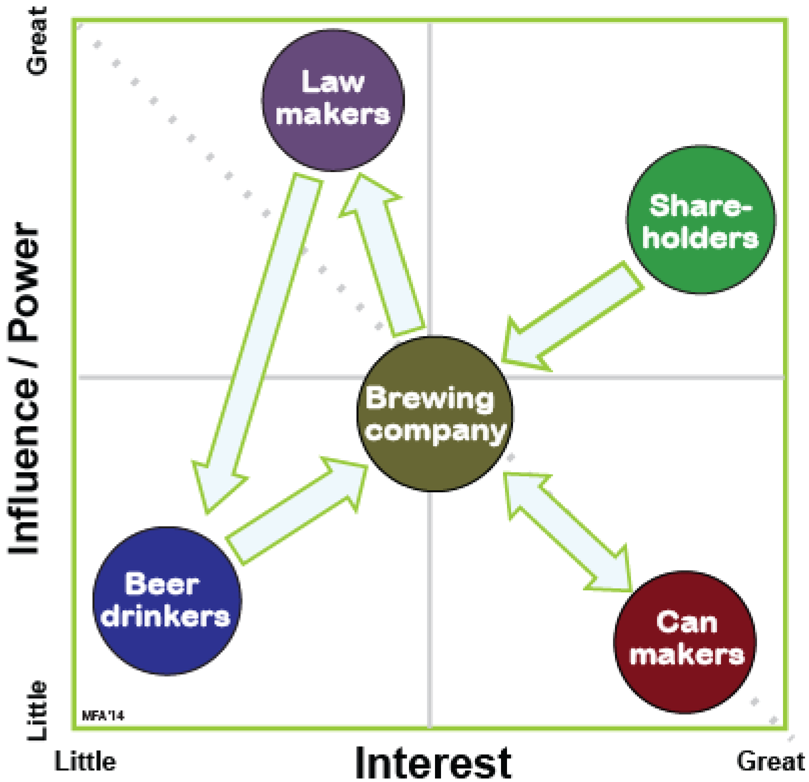
Prime objective and scale

- *Reduce energy and CO_2 emission by change from Al to Fe cans*
- *5×10^8 cans per year*
- *Progress in a year*

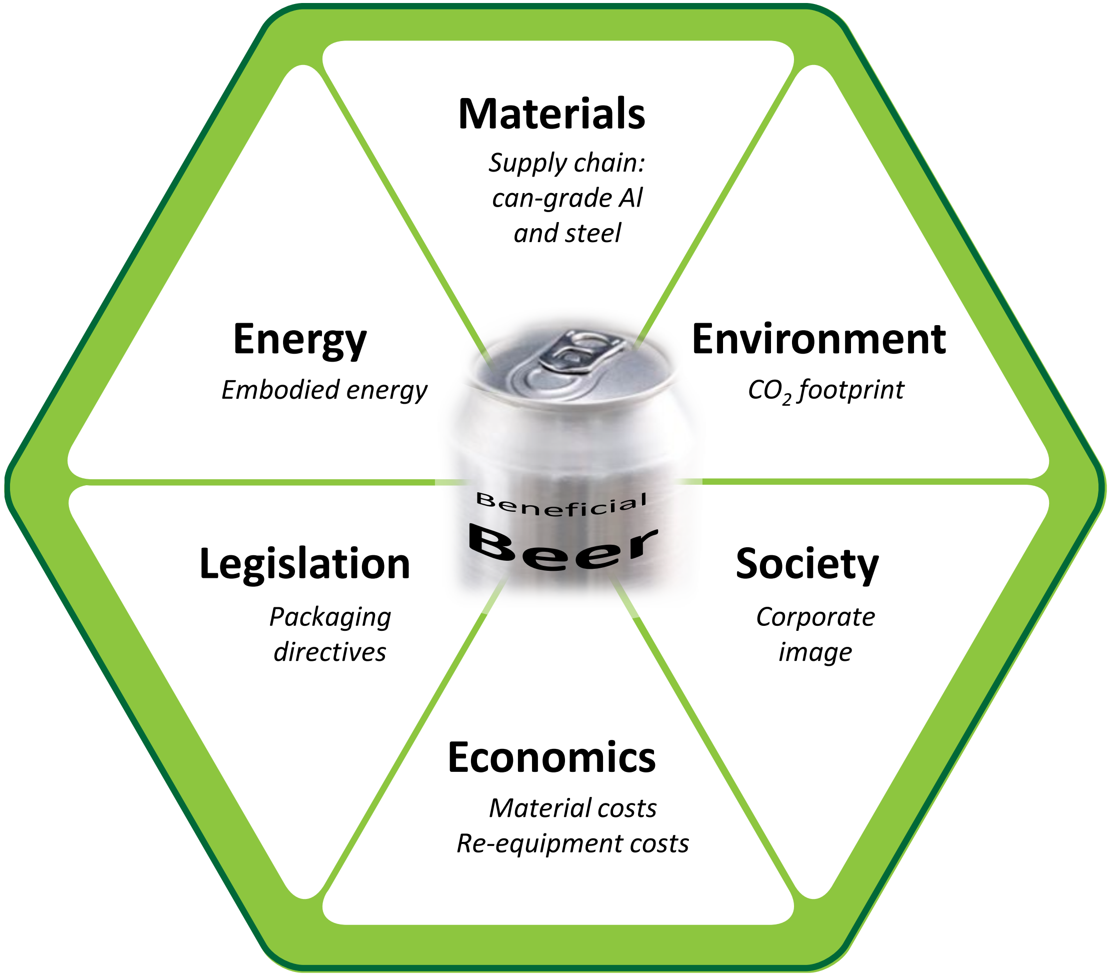
Step 2: Stakeholders and concerns

- Shareholders
  – *reduce energy and CO_2 emissions*
- Can makers
  – *loss or gain of market share*
- Beer drinkers
  – *little interest in can material*
- Law makers
  – recycling targets
- Beneficial Brewery
  – *respond to shareholder concerns*

Stakeholder diagram



Step 3: Fact-finding



MFA 2014

Fact-finding: Materials / Energy

Materials

- *Neither aluminum nor steel are "critical" materials*
- *Can weight : Aluminum 13 grams*
  Steel 44 grams

Aluminum Steel

Energy

Embodied energy, can-grade Al	*110 MJ/kg*	*Factor 6*
Embodied energy, can-grade steel	*18 MJ/kg*	
Embodied energy, Al can	*1.4 MJ*	*Factor 1.7*
Embodied energy, steel can	*0.8 MJ*	

Full LCA of cans suggests difference in final energy per can is negligible*

* http://www.apeal.org/uploads/Library/LCA%20study.pdf

Fact-finding: Environmental / Legislation / Economics

Environment

- CO2 emissions per can: same conclusion as energy; same LCA source

Legislation

- EU Packaging Directive (1994) – Maximize recovery and recycling of packaging

Economics

Cost, can-grade Al	≈ 1.7 $/kg	Factor4
Cost, can-grade steel	≈ 0.4 $/kg	
Material cost, Al can	≈ 2.2 ¢	Factor 1.1
Material cost, steel can	≈ 2.0 ¢	

* Cost, Legislation retrieved from the CES EduPack Sustainability DB

Step 4: Impact on the Three Capitals (overview)

- Negligible reduction in emissions – Objective not achieved

Natural capital
(Planet)

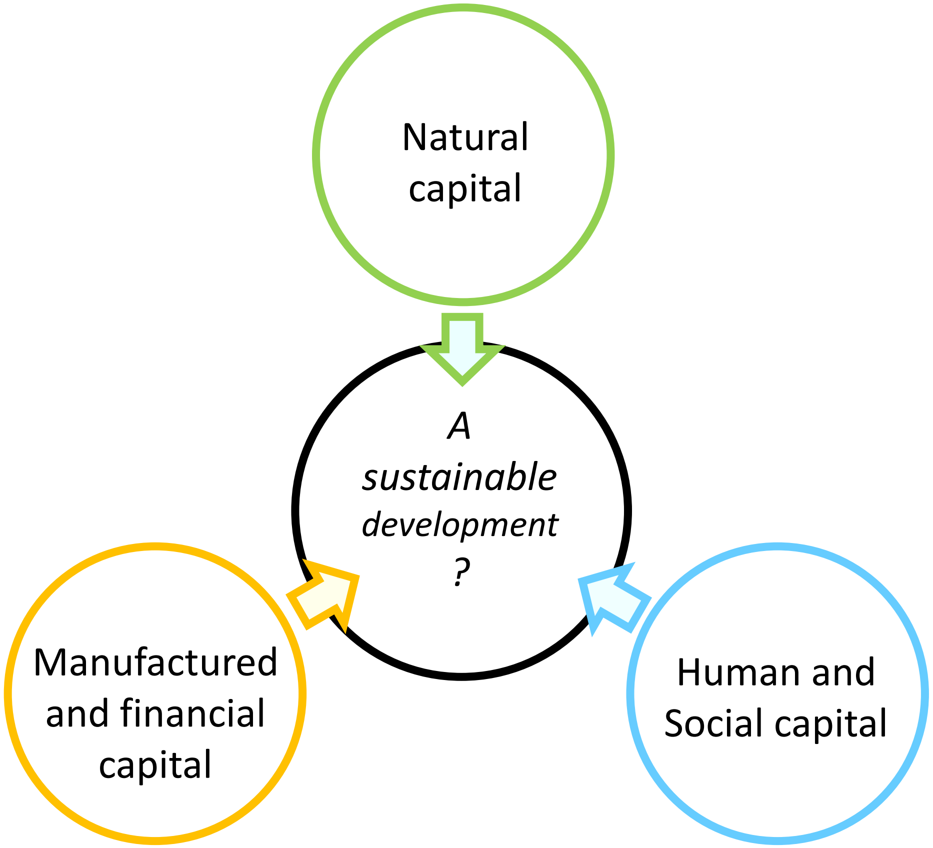
Manufactured and financial capital
(Prosperity)

Human and Social capital
(People)

- Re-equipping filling line to deal with difference can material is expensive and disruptive

- Shareholder are influential stakeholders – seek other ways to meet their eco-concerns

Step 5: Reflection



Short term

- Many negatives (uncertain eco benefit, costly, disruptive change

Longer term

- Could reconsider if re-equipping for other reasons

Alternative strategies?

- Support legislation for deposit on cans and mandatory recycling ?

Sustainable Development Projects

This resource:

- Projects
  - Project 1 : Greener Beer Cans
  - Project 2 : Expanding Biopolymer Production
  - Project 3 : Electric Cars
- Resources

Students

- Problem statement
- Templates
- Assessing Sustainable Development

Educators

- Summary Presentation
- Sample Analysis
- Related Projects

A White Paper called Materials and Sustainable Development and a book of the same name describe this methodology and the rationale behind it in more detail.
http://teachingresources.grantadesign.com/Type/Papers/PAPSSDEN13

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