Aalto University
School of Arts, Design
and Architecture

Sustainable design S5

Tatu Marttila

4.5.2020

Agenda

9.15–9.25 Recap from previous sessions

9.25–10.15 Researching sustainability in design & sustainability assessment

- *Researching & assessing sustainability – challenges*
- *Life-cycle analysis (LCA) and design*
- *Materials research and selection*
- *Assessing sustainability – the process*

10.30–11.10

Assessment exercise *(breakout rooms)*

Discussion *(back to main room at 10.50)*

11.10–11.40 Granta Edupack introduction *(on Aalto computers!)*

11.40–11.45 Wrap-up & next session

Researching sustainability in design

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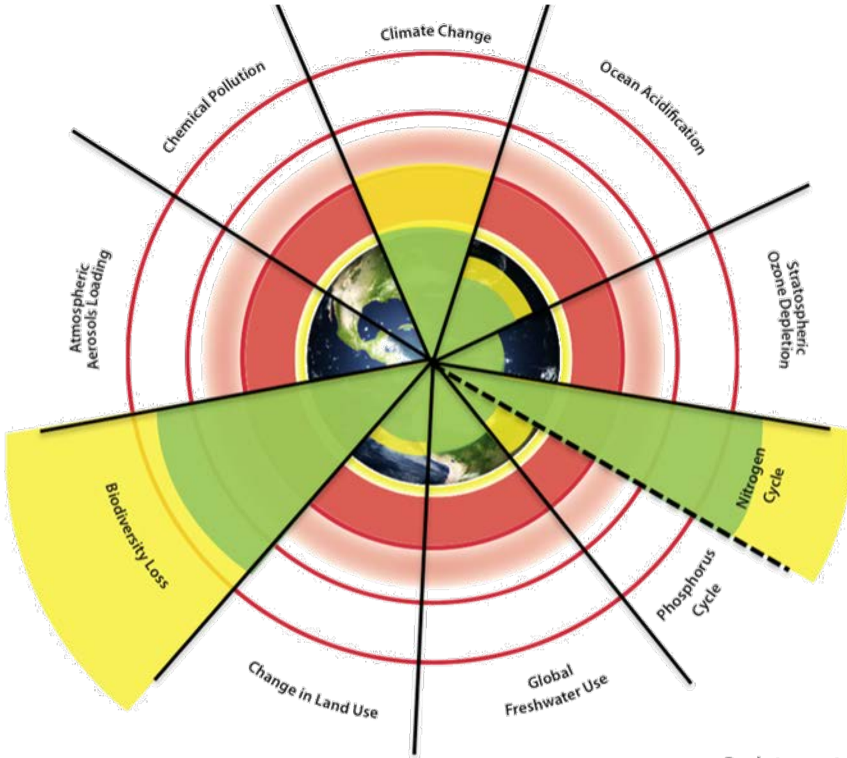
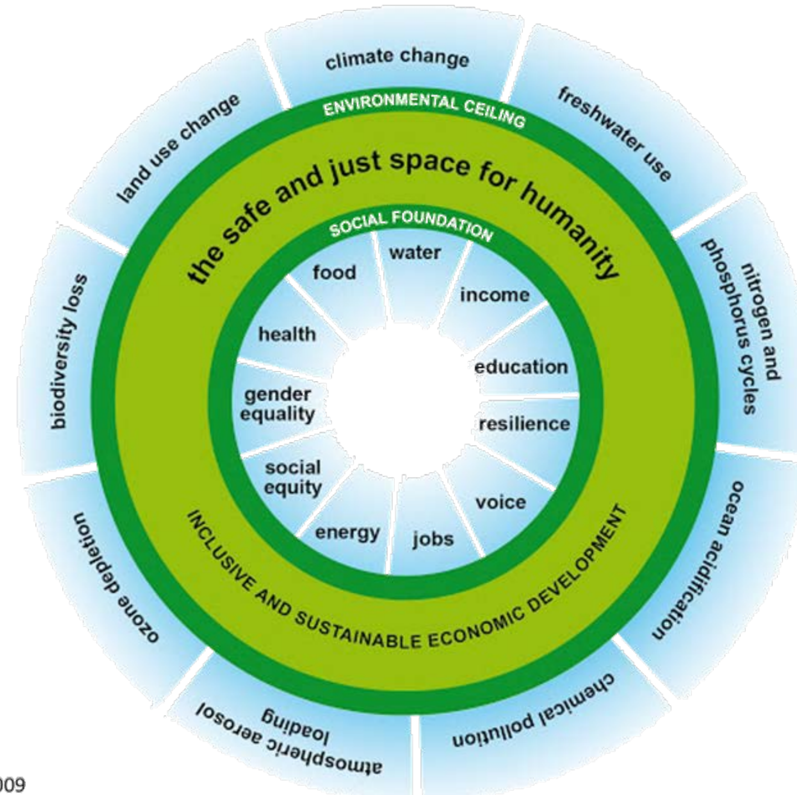
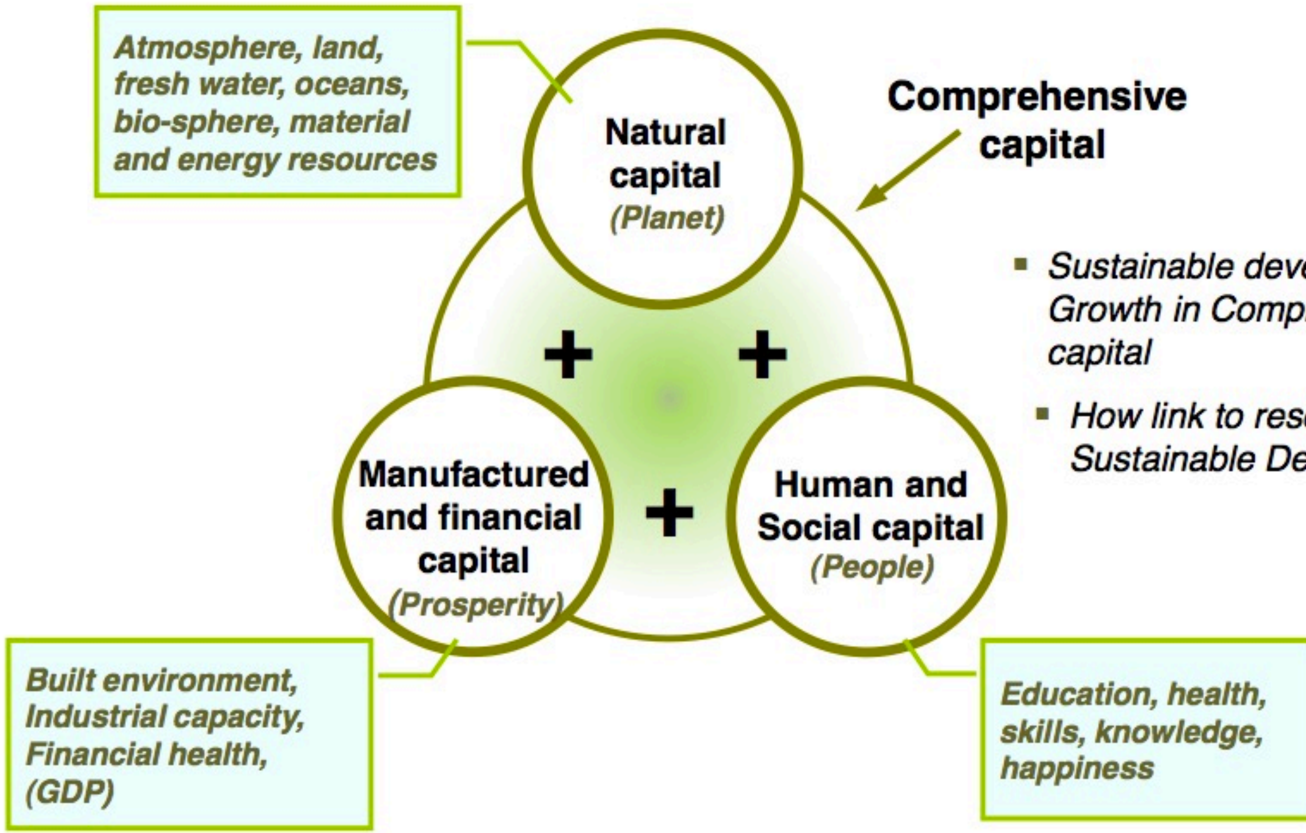
Sustainability, a complex concept…



Rockstrom et al., 2009



Growing comprehensive capital…



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

Source: Ashby et al. (2013) Materials & SD

Sustainability in design

Considerations: “Sustainability” vs. “Sustainable development”?

Triple bottom line (TBL) Reporting:

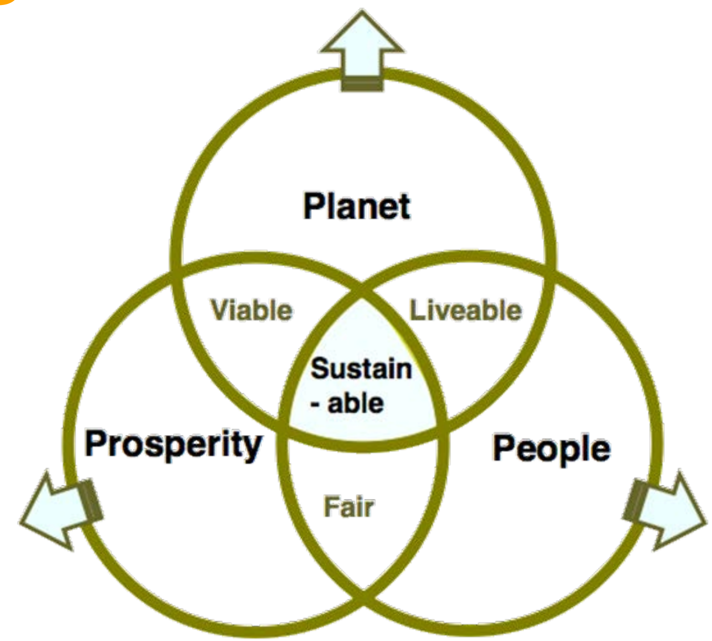
Financial bottom line

Social / ethical performance

Environmental performance

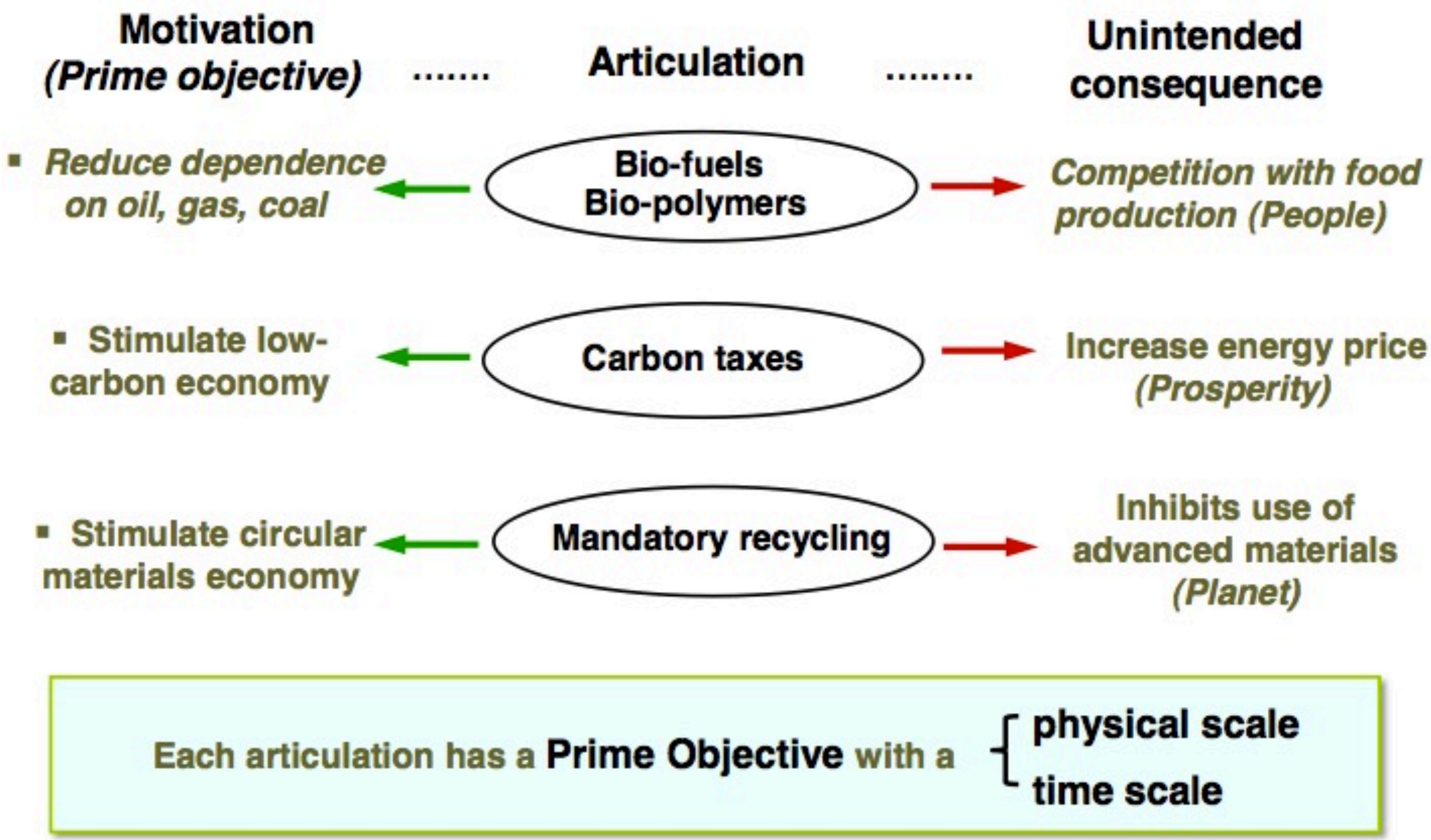
(Elkington, 1994)

Decouple the circles – unpack their meaning…



Source: Ashby et al. (2013) Materials & SD

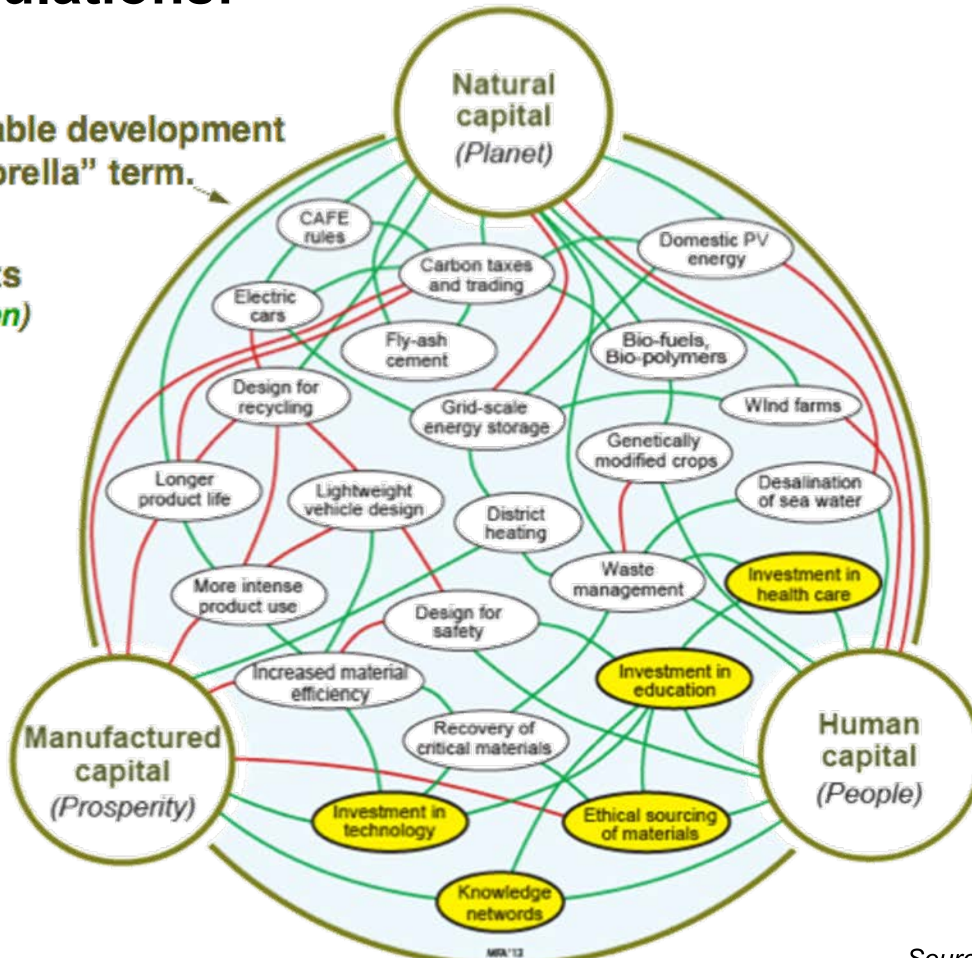
Several actions / techs / “solutions” claim to support sustainability, but:



Source: Ashby et al. (2013) Materials & SD

Mapping articulations:

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

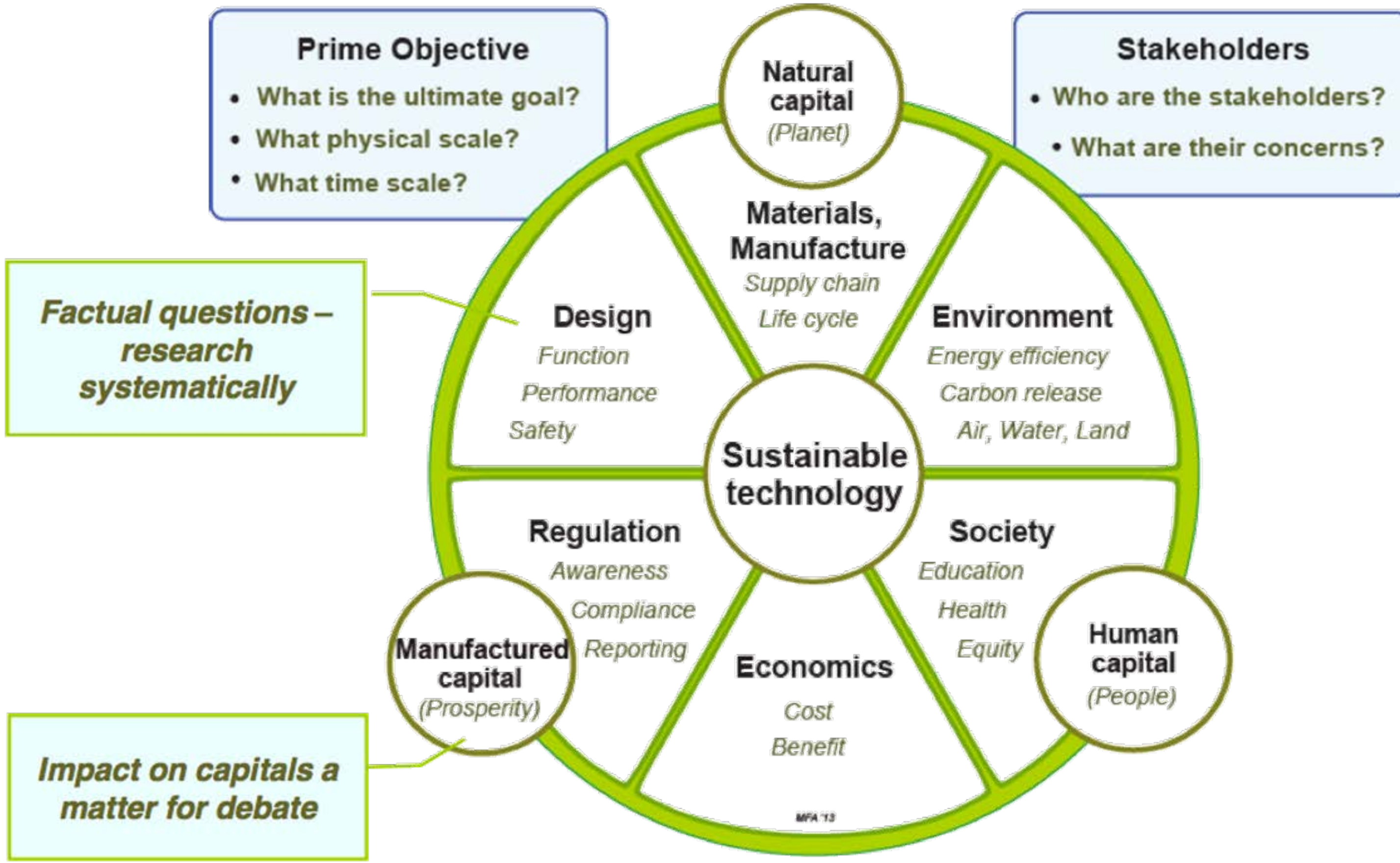


What can we distil from this picture? Group under:

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

Source: Ashby et al. (2013) Materials & SD

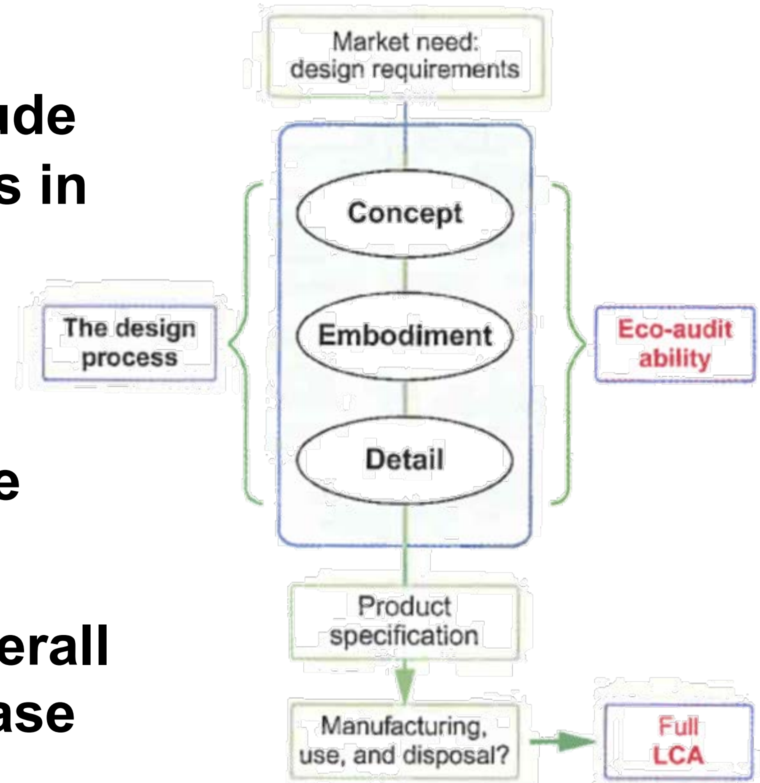
Analysing articulations:



Source: Ashby et al. (2013) Materials & SD

Design and life-cycle impact assessment

- Sustainable design needs to include assessment / reflection of impacts in different phases of product-life
- One mainly used approach in ecodesign is life-cycle analysis (LCA) and the following “life-cycle design”
- Life-cycle analysis (LCA) is an overall term of the assessment of life phase impacts of products and systems



LCA, SLCA, and S-LCA

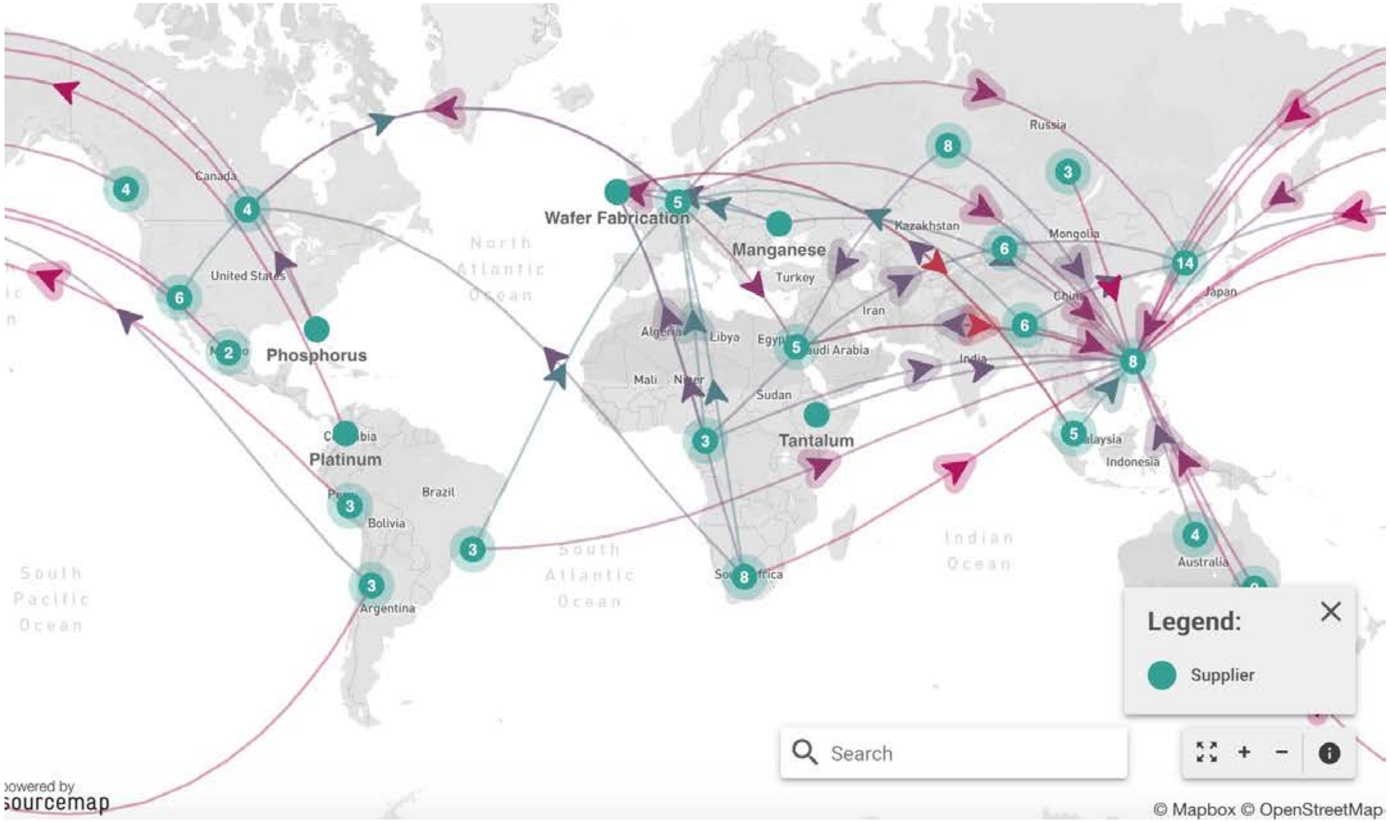
- **In general design tools for life cycle design range from guidelines and checklists to qualitative tools, light-weight eco-auditing tools and finally to full-scale quantitative LCA research, often made by specialized consults**
- **SLCA refers to easy-to-use “streamlined” LCA tools; They combine both qualitative and quantitative approaches**
- **Social LCA (S-LCA) moves focus to production “hotspots” and assessment of stakeholder impacts through UN HDI goals (see eg. UNEP’s S-LCA manual)**

Materials research

- **Products and services embodying materials**
- **Resources and materials as “shared capital”**
- **”Biological” and “Technological” material cycles**
- **Renewable and non-renewable materials**
- **Materials and design:**
  - Embodied energy, energy in use;
  - Toxicity; End-of-Life

-> Accessible data to compare!

Mapping material flows:



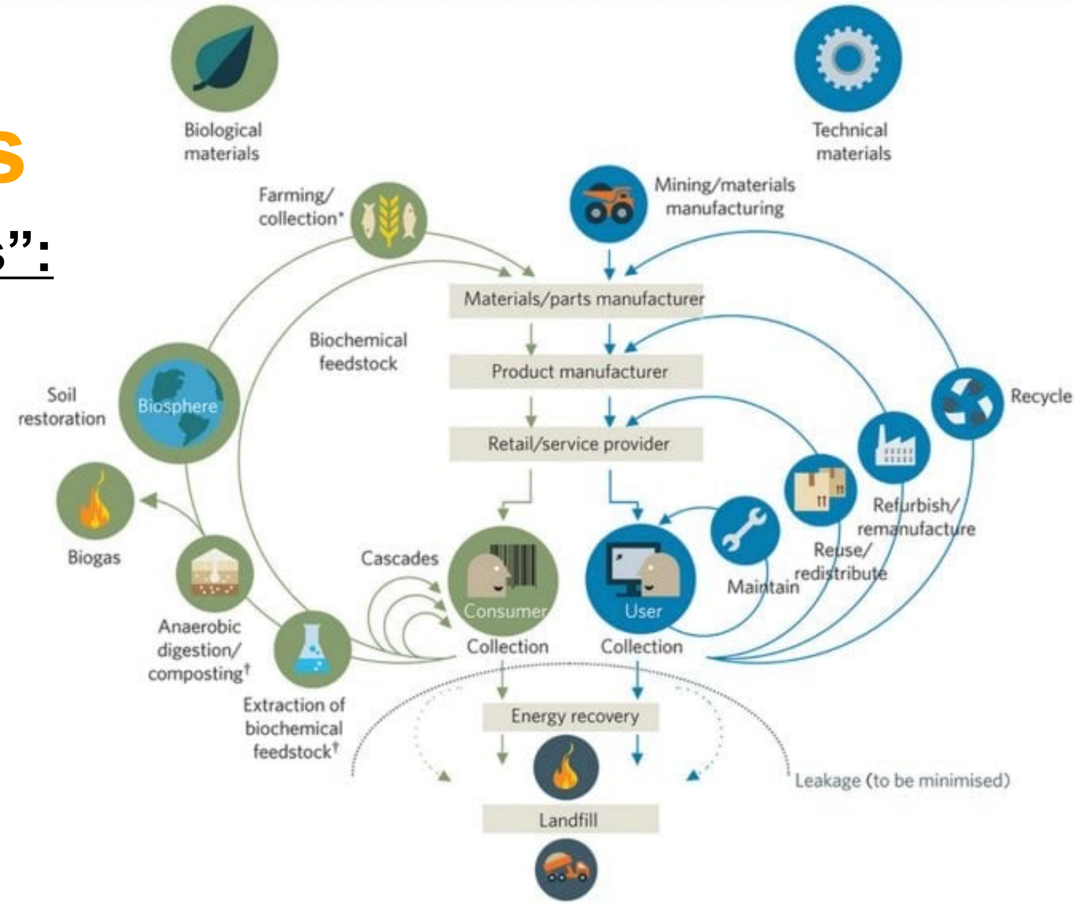
Several material cycles

<u>Different "metabolisms":</u>

- **Biological cycle**
- **Technical cycle**

Circular models: Incompatible cycles should not cross-contaminate

-> Design guideline!



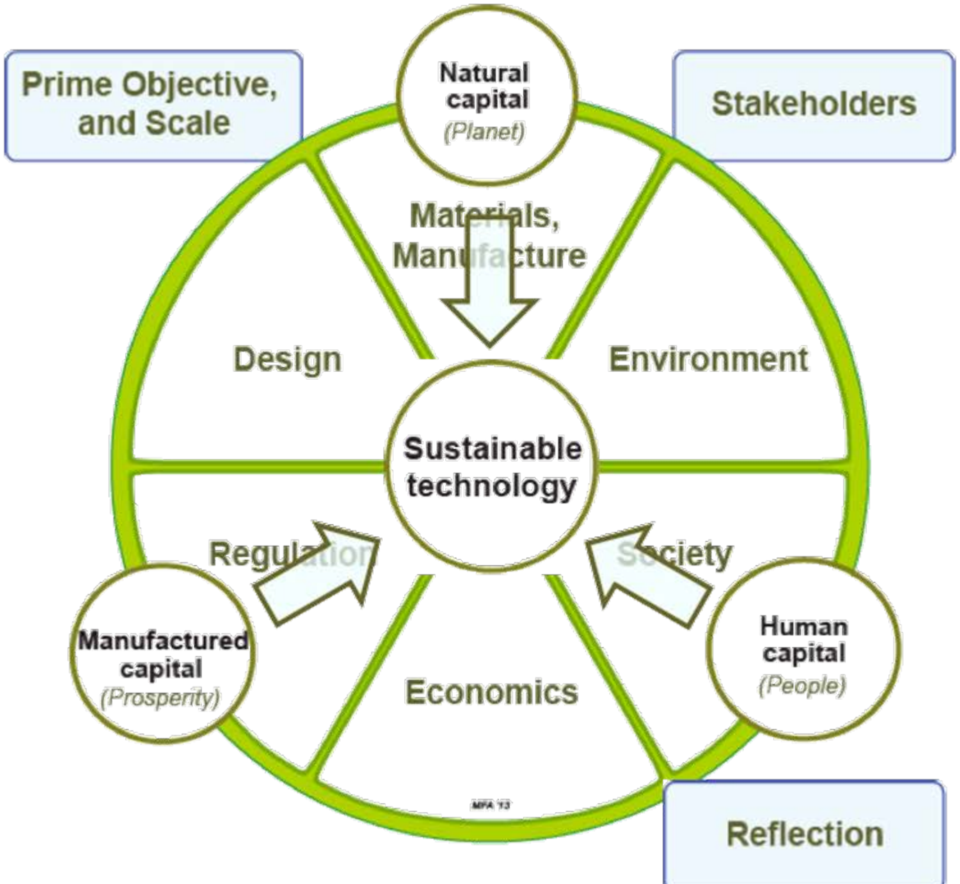
Sustainability assessment

Sustainability assessment process in design

Steps to assess sustainability impacts and potential:

1. Identify prime objective for design action (product / service / process etc.)
2. Define system boundaries for the assessment
3. Review stakeholders and both production system and product components
4. Perform "fact-finding" on stakeholders and components (Materials & Manufacturing; Environment; Society; Economics; Regulation; Design)
5. Integration back into communicative message (Natural capital; Manufactured capital; Human capital)

Assessing sustainability impacts / potential:



Step 1: Clarify Objective

Step 2: Stakeholders

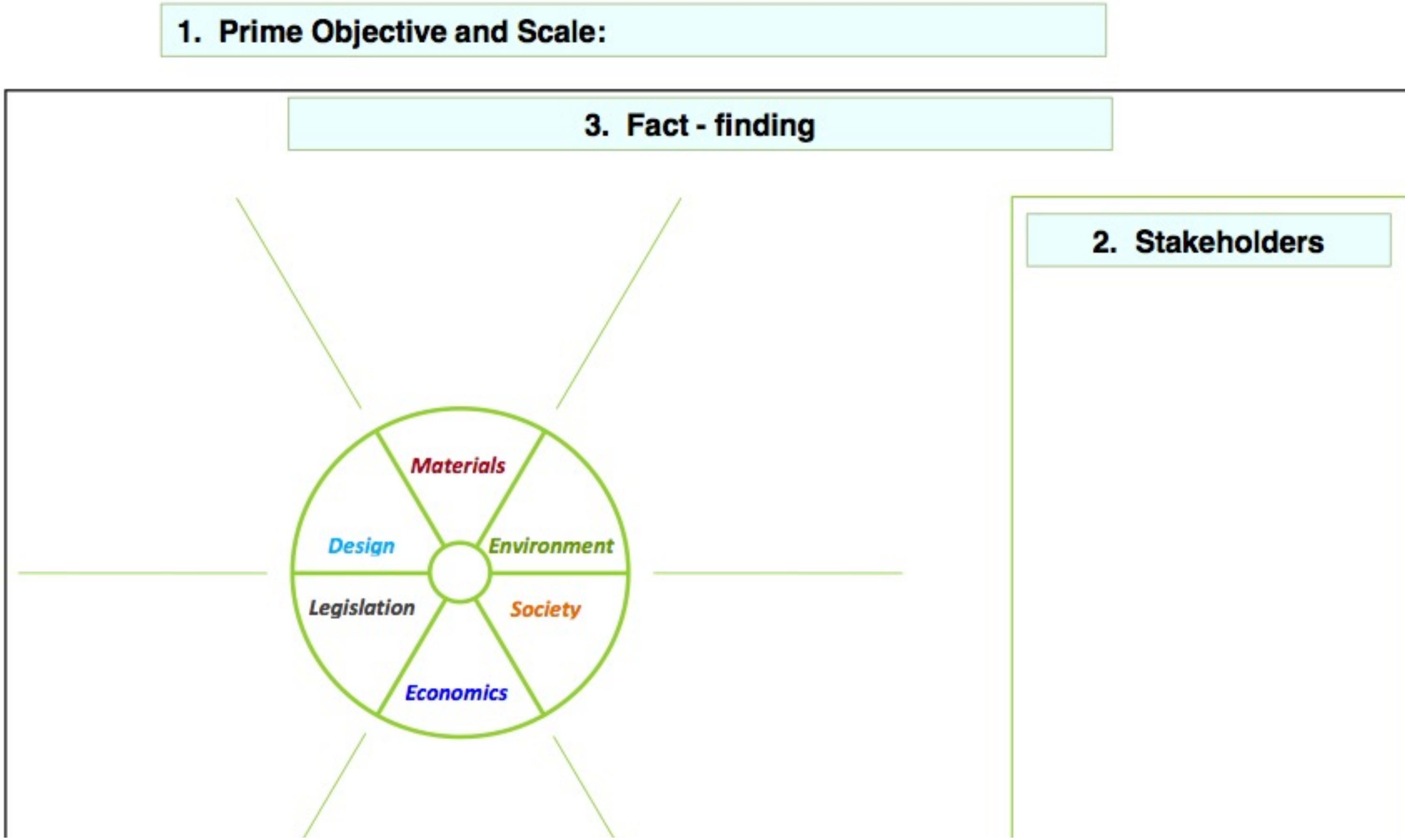
Step 3: Fact finding
- *objective*

Step 4: Integration
- *subjective*

Step 5: Reflection

Source: Ashby et al. (2013) Materials & SD

Granta Edupack fact-finding sheet:



Life-cycle assessment process

LCA process:

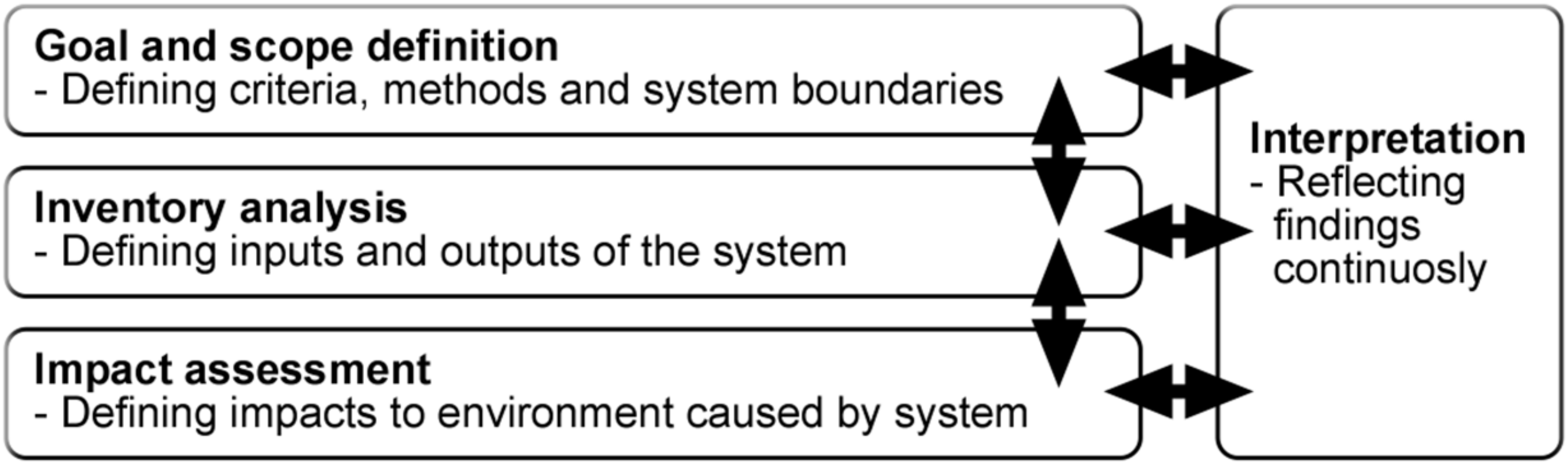


Figure 2. The process of LCA (according to ISO 14040 and ISO 14044).

Life-cycle phases, inputs and outputs, and system boundaries:

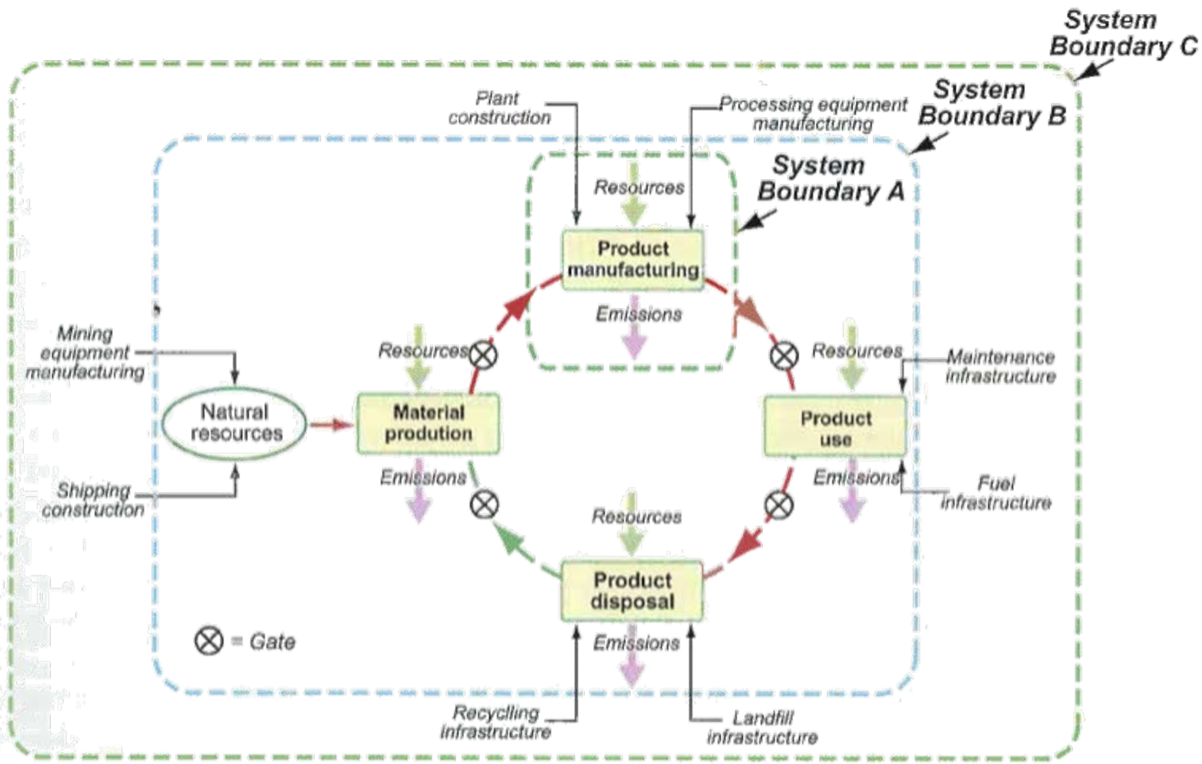
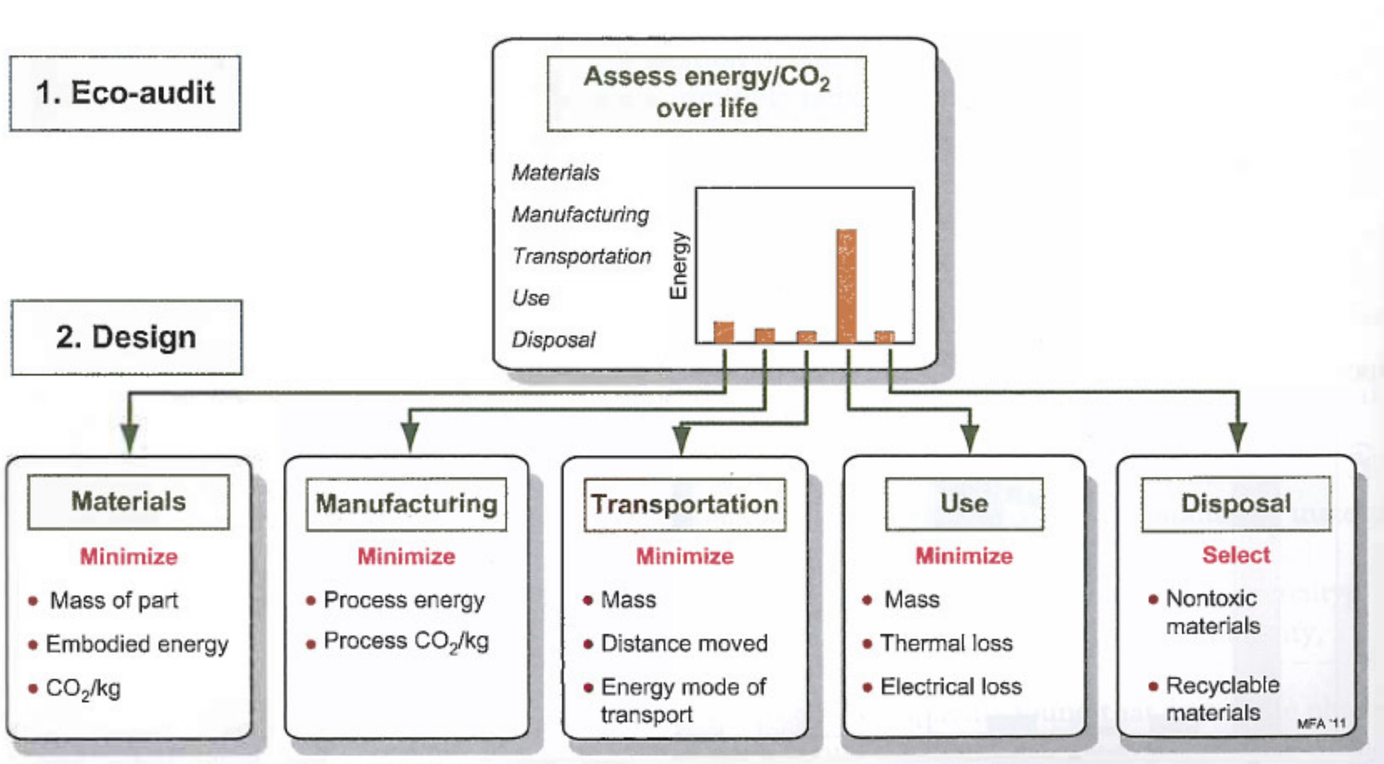


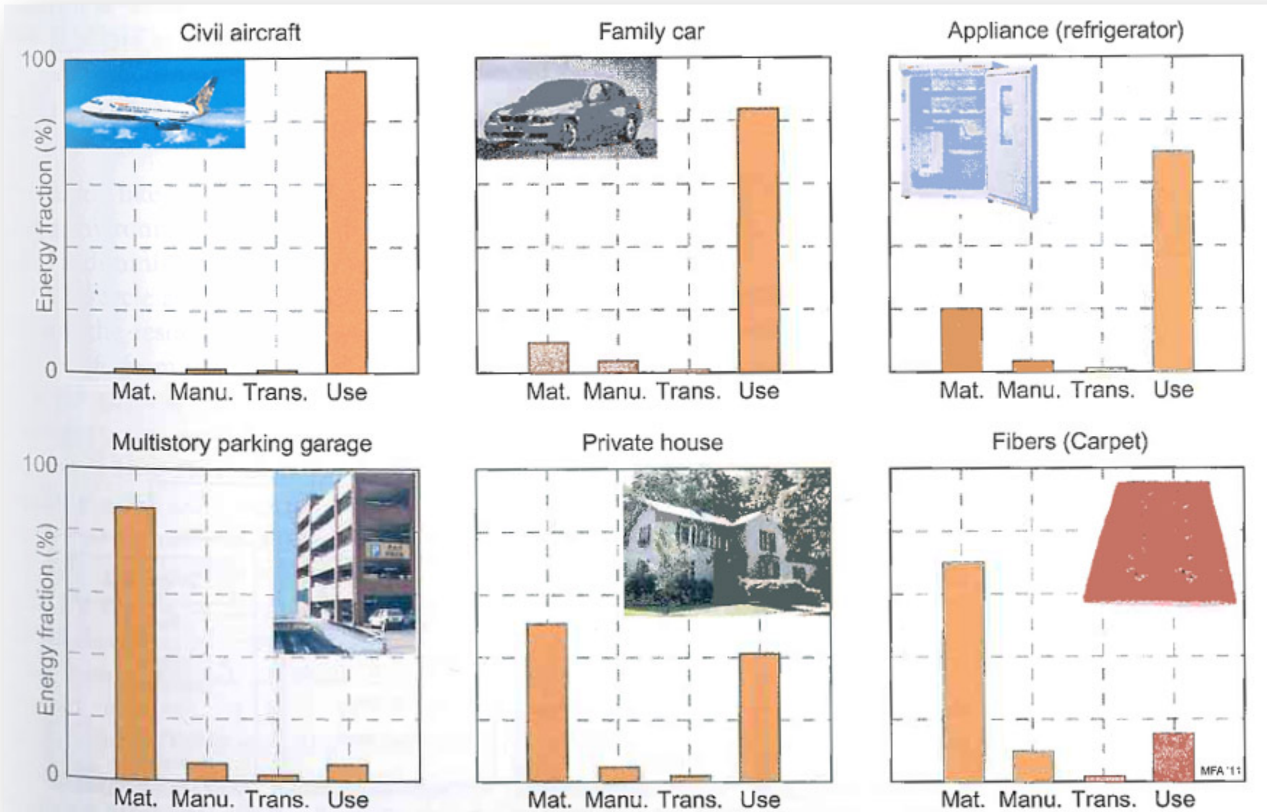
FIGURE 3.3 *LCA system boundaries with the flows of resources and emissions across them. System Boundary A encloses a single phase of the lifecycle. System Boundary B encloses the direct inputs and emissions of the entire life. It does not make sense to place the system boundary at C, which has no well-defined edge.*

Assessing (and improving) impacts throughout life-cycle phases:



Source: Ashby, M. (2012) Materials and the Environment: Eco-Informed Material Choice

Different "impact profiles" for different products:



Source: Ashby, M. (2012) Materials and the Environment: Eco-Informed Material Choice

Listing materials and processes:

Component and material list accompanied with processes and EoL options helps in managing the assessment process.

Example materials list of a sneaker:

	Component name	Material	Process	EoL
1	Upper textile	Nylon (synthetic polymer)	Textile production	Landfill?
1	Lining and insole	Nylon (synthetic polymer)	Textile production	Landfill?
1	Sole: outer surface	Carbon rubber		Landfill?
1	Sole: inside	Polyurethane foam	Extrusion molding	Landfill?

Managing information – MET matrix:

MET (materials, energy, toxicity) matrix/table is an SLCA tool/method to manage research in eco-auditing and LCA processes:

Life phase	Materials	Energy	Toxicity
Raw materials	List of components and materials	Embodied energy	Issues in materials production; eg. CO_2
Production processes	List of production processes	Energy consumption in production	Eg. CO_2 in manufacturing
Transport/ logistics	Infrastructure in transport & logistics	Energy consumption in logistics	Means of transport? CO_2 per kg?
Use phase	Materials needed during use (eg. Coffee filters)	Energy consumption during use	Waste of consumables
End-of-Life (EoL)	EoL choices for components/materials	Impacts of EoL choices	Impacts of EoL choices

MET matrix: Coffee machine (1/2)

	Use of MATERIALS (Inputs) M	Use of ENERGY (Inputs) E	TOXIC EMISSIONS (Outputs: emissions, effluent, waste) T
Obtainment & consumption of materials and components	- Copper (exhaustible material) (0,05 kg). - Steel (0,3 kg) - Aluminium (0,3 kg) - Polystyrene (PS) (1 kg) - PVC (0,1 kg) - Glass (0,4 kg) - Printed circuits (0,1 kg)	- High energy content in materials (Al, Cu) - Transport of ready assembled printed circuits from Asia (0.03 kWh)	- Fire retardants in printed circuit boards (↓) - Liquefiers for injection moulding (↓) - PS: Benzene emissions (↓) - PUR: Isocyanate (↓) - Emissions due to painting and gluing (↓)
Factory production	- Auxiliary materials (welding materials, degreasers and lubricants for the machines of the production system of the company, etc.) (↓)	- Energy in miscellaneous processes (Polystyrene moulding, aluminium extrusion, welding etc.) (↓)	- Metallic and plastic waste (offcuts and rejects) (↓) - Remainder of lubricants and degreasers for machines. (↓)
Distribution	- Product packaging. (polyethylene bag: 0.3 kg and cardboard: 0.1 kg) - Cardboard for repacking (↓) - Instruction manual (0,04 kg).	- Diesel fuel for transport (lorries) (0.3 kWh)	- Emissions from diesel fuel combustion (↓). - Remainder of packing: - Polyethylene bag (recyclable) (0.3 kg) - Cardboard (recyclable) (0.1 kg)

See: http://wikid.io.tudelft.nl/WikID/index.php/MET_matrix

MET matrix: Coffee machine (2/2)

Use or utilisation	***- OPERATION*** - Paper filters (7,3 kg) - Coffee used (65 kg)* - Cleaning materials (↓) - Water for cleaning (10.950 l)	- Energy consumption (375 kwh) a.- Heating: 281,25 kwh b.- Maintenance: 93,75 kwh **	- Waste from consumables (filter with coffee dregs, etc.) (72,3 kg) - Waste water from cleaning (10.950 l). - Emissions deriving from energy consumption (2305 kg CO_2).
	MAINTENANCE - Parts which are easily breakable (↓).	- Transport of maintenance providers (↓)	- Remainder of replaced parts (↓).
End of life system. Final disposal			***RECYCLING*** - Glass (0,4 kg) - Plastics (1,1kg) - Instruction manual (0,04 kg) ***DISPOSAL*** - Printed circuit board (0,1 kg) - Copper (0,05 kg) - Aluminium (0,3 kg) - Steel (0,3 kg)

Priority impacts (detected with the aid of environmental consultant expert in Ecodesign).

* Consumption of coffee is allowed for at one 250 g packet per week throughout the 5 years of estimated lifetime. Despite the fact that the coffee is quantitatively one of the highest figures, it is the only one which cannot be minimised, so it has not been considered to be a priority.

** This breakdown may facilitate the generation of ideas for improvement on this environmental aspect.

Assessing impacts of service – MIPS approach:

Material input per service unit (MIPS):

- An assessment method by European Wuppertal Institute
- Used to calculate impacts per "service unit", eg. per km travelled, meal served, or use of a product
- Impact indicators in five categories
- Complex calculations; Limited library of values

I. Abiotic raw materials

- mineral raw materials (used extraction of raw materials, such as ores, sand, gravel, slate, granite)
- fossil energy carriers (amongst others coal, petroleum oil, petroleum gas) unused extraction (overburden, gangue etc.)
- soil excavation (e.g. excavation of earth or sediment)

II. Biotic raw material

- plant biomass from cultivation
- biomass from uncultivated areas (plants, animals etc.)

(Domesticated animals are already part of the technosphere, and are therefore referred back to biomass taken directly from nature, e.g. plant or animal fodder.)

III. Earth movement in agriculture and silviculture

- mechanical earth movement or
- erosion

IV. Water

(separated according to processing and cooling water)

- surface water
- ground water
- deep ground water (subterranean)

V. Air

- combustion
- chemical transformation
- physical transformation (aggregate state)

See: http://pavogy.web.elte.hu/Kornyez/Koz_kis/MIPS/ws27e.pdf

Break

Exercise

Split in 5 breakout rooms, discuss of general impacts:

- *Group 1: Concrete*
- *Group 2: Steel*
- *Group 3: Paper & cardboard*
- *Group 4: Cotton*
- *Group 5: Plastics*

Discuss in groups (20 min), then present findings to others in main room at 10.55.

For the board, go to:
https://docs.google.com/presentation/d/1JEtRhO-se4qzG0mNYCUDz6VP-Va94gFnvJiGlpjfzKU/edit?usp=sharing

Electronic products & waste (example):

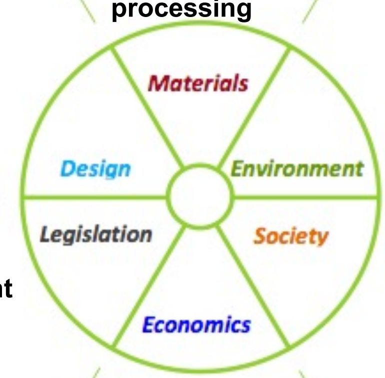
1. Prime Objective and Scale: *12 million tons annually in EU (amount of WEEE waste in 2020)*

3. Fact - finding

Materials:
- Critical materials involved
- Toxics of production
- High energy consumption in production/ processing

Design:
- Highly compact design (eg. phones)
- Rather short product life
- Difficult recycling

Environment:
- Production/ processing/ transport impacts
- Mining industry impacts / toxicity
- Old products are inefficient
- Severe EoL issues



Legislation:
- Carbon trade & Paris agreement
- EU eco-design directives
- Mandatory recycling (PRO's)

Society:
- Crucial in contemporary life (eg. phones)
- Labor issues in mining, production, processing, EoL?

Economics:
- Value of markets is high, but low market for recycled materials (eg. plastics)
- Cost of recycling is high

2. Stakeholders

Important stakeholders:

- Raw material industry (incuding mining)
- Manufacturing industry
- Policymakers
- Consumers and associations
- EoL / PRO's & recyclers

Granta Edupack introduction

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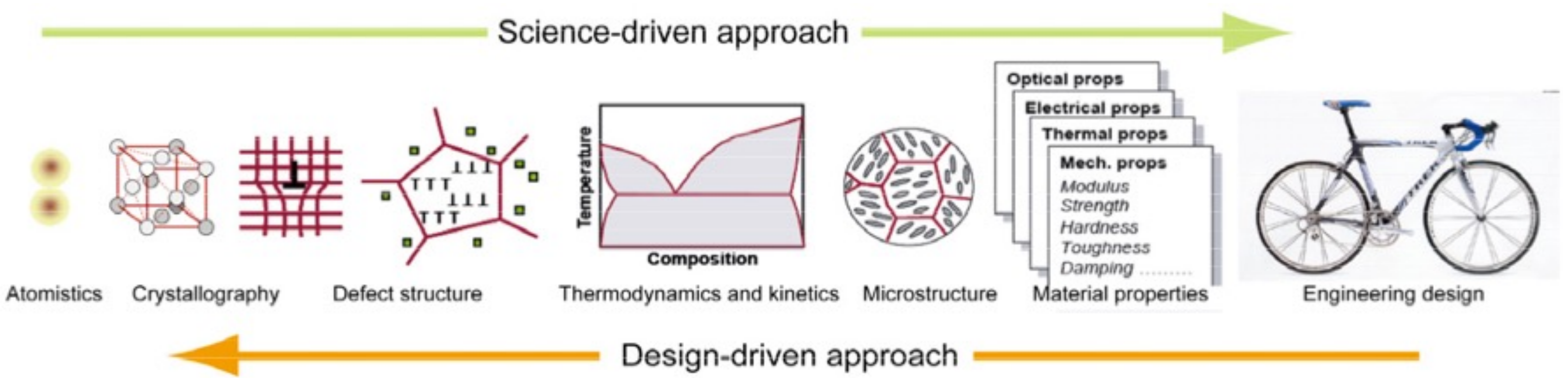
Approaching Material Science

Two main approaches to material sciences: Science-driven & design-driven

Design-driven approach begins with specification of design requirements and translation into material choices.

Assessing sustainability also entails analysis of impacts of the whole production chain.



Granta Edupack database

Grantadesign’s Edupack Tool (previously Cambridge Engineering Selector) is a program with database that have information tables on legislation & regulations, materials, processes, nations and even many producers.

It can be used to easily compare different materials and their qualities and to assist in material selection.

It can be also used to assess products’ impacts on both environmental and also to some extent on societal dimensions (or system parts like service elements).

On Aalto computers!

Two main processes with Edupack

Materials selection:

- **Materials comparison can be done by combining information from the several different tables considering material qualities and information related to them (e.g. Nations of the world –table).**

Impacts assessment:

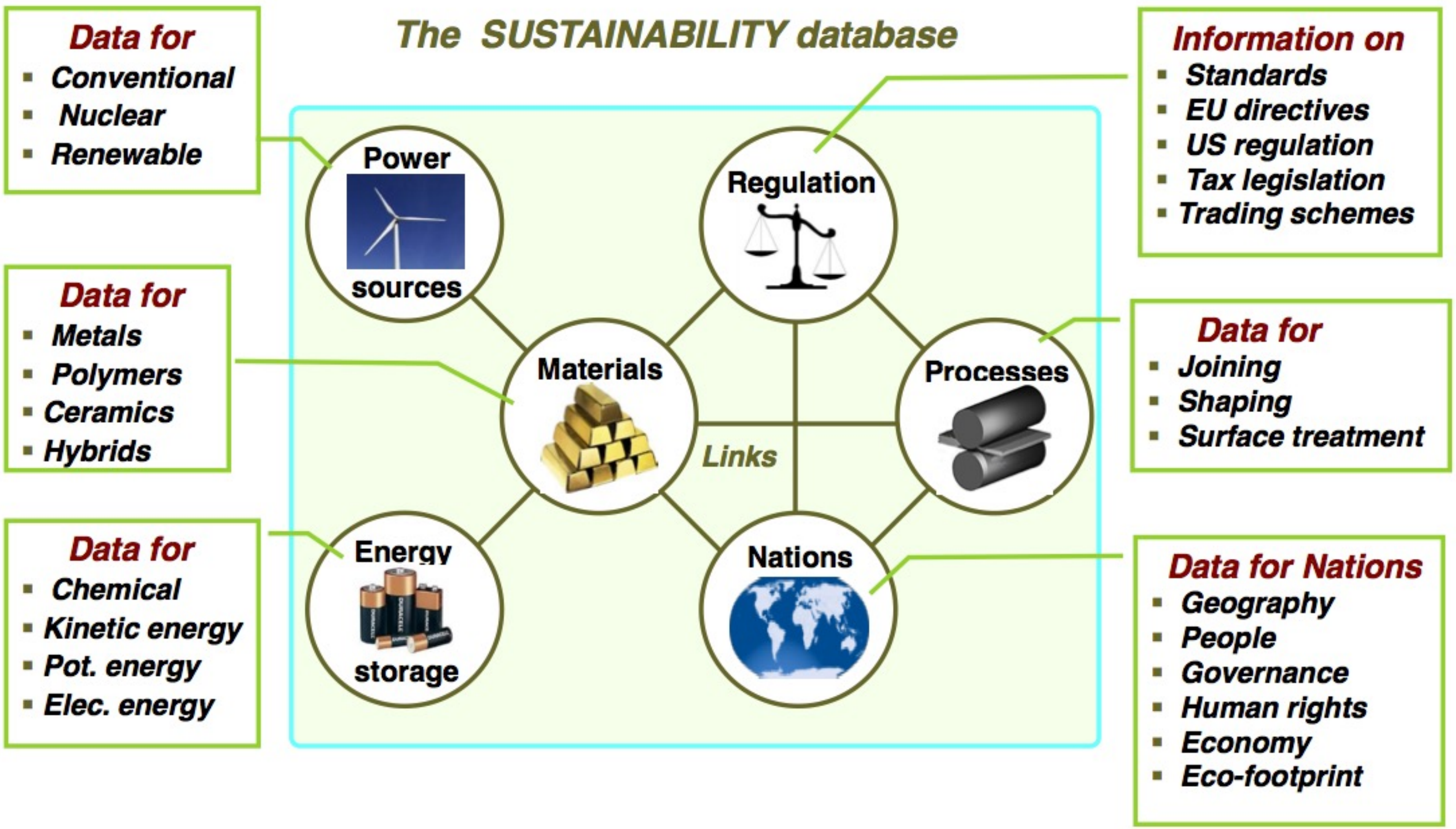
- **Products (or system elements) can be assessed with SLCA type of impact-assessment tool (indicating values from data tables)**
- **Products' assessment values can be compared with each other**

Information in Edupack

In the Granta Edupack database there are several datatables, regarding:

- **Legislation & regulations**
- **Material Universe**
- **Process Universe**
- **Nations of The World**
- **Producers**

Datatables to assist sustainable design process:



Source: Ashby et al. (2012) Materials & SD

Datatable record sheets:

Injection molding

No other process has changed product design more than INJECTION MOLDING. Injection molded products appear in every sector of product design: consumer products, business, industrial, computers, communication, medical and research products, toys, cosmetic packaging and sports equipment. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected.
Thermoplastics, thermosets and elastomers can all be injection molded. Co-injection allows molding of components with different materials, colors and features. Injection foam molding allows economical production of large molded components by using inert gas or chemical blowing agents to make components that have a solid skin and a cellular inner structure.

Shape

Circular prismatic	True
Non-circular prismatic	True
Solid 3-D	True
Hollow 3-D	True

Physical attributes

Mass range	0.001	-	25	kg
Range of section thickness	0.4	-	6.3	mm
Tolerance	0.07	-	1	mm
Roughness	0.2	-	1.6	μm
Surface roughness (A=v. smooth)	A			

Process characteristics

Primary shaping processes	True
Discrete	True

Economic attributes

Relative tooling cost	very high		
Relative equipment cost	high		
Economic batch size (units)	10000	-	1e6

Design guidelines
Injection molding is the best way to mass-produce small, precise, polymer components wit finish is good; texture and pattern can be easily altered in the tool, and fine detail reproduces molded onto the surface of the component (see In-mold Decoration). The only finishing c sprue.

Technical notes
Most thermoplastics can be injection molded, although those with high melting tempera Thermoplastic-based composites (short fiber and particulate filled) can be processed provi large. Large changes in section area are not recommended. Small re-entrant angles and though some features (e.g. undercuts, screw threads, inserts) may result in increased toolin be used with thermosets and elastomers. The most common equipment for molding ther

Polypropylene (PP) (CH2-CH(CH3))n

Polypropylene, PP, first produced commercially in 1958, is the younger brother of polyethylene - a very similar molecule with similar price, processing methods and application. Like PE it is produced in very large quantities (more than 30 million tons per year in 2000), growing at nearly 10% per year, and like PE its molecule-lengths and side-branches can be tailored by clever catalysis, giving precise control of impact strength, and of the properties that influence molding and drawing. In its pure form polypropylene is flammable and degrades in sunlight. Fire retardants make it slow to burn and stabilizers give it extreme stability, both to UV radiation and to fresh and salt water and most aqueous solutions.

General properties

Density		890	-	910	kg/m^3
Price	*	1.89	-	2.07	USD/kg

Mechanical properties

Young's modulus	0.896	-	1.55	GPa
Shear modulus	0.316	-	0.548	GPa
Bulk modulus	2.5	-	2.6	GPa
Poisson's ratio	0.405	-	0.427	
Yield strength (elastic limit)	20.7	-	37.2	MPa
Tensile strength	27.6	-	41.4	MPa
Compressive strength	25.1	-	55.2	MPa
Elongation	100	-	600	%
Hardness - Vickers	6.2	-	11.2	HV
Fatigue strength at 10^7 cycles	11	-	16.6	MPa
Fracture toughness	3	-	4.5	MPa.m^0.5
Mechanical loss coefficient	0.0258	-	0.0446	

Thermal properties

Melting point	150	-	175	°C
Glass temperature	-25.15	-	-15.15	°C
Maximum service temperature	100	-	115	°C
Minimum service temperature	-123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.113	-	0.167	W/m.°C
Specific heat capacity	1.87e3	-	1.96e3	J/kg.°C
Thermal expansion coefficient	122	-	180	µstrain/°C

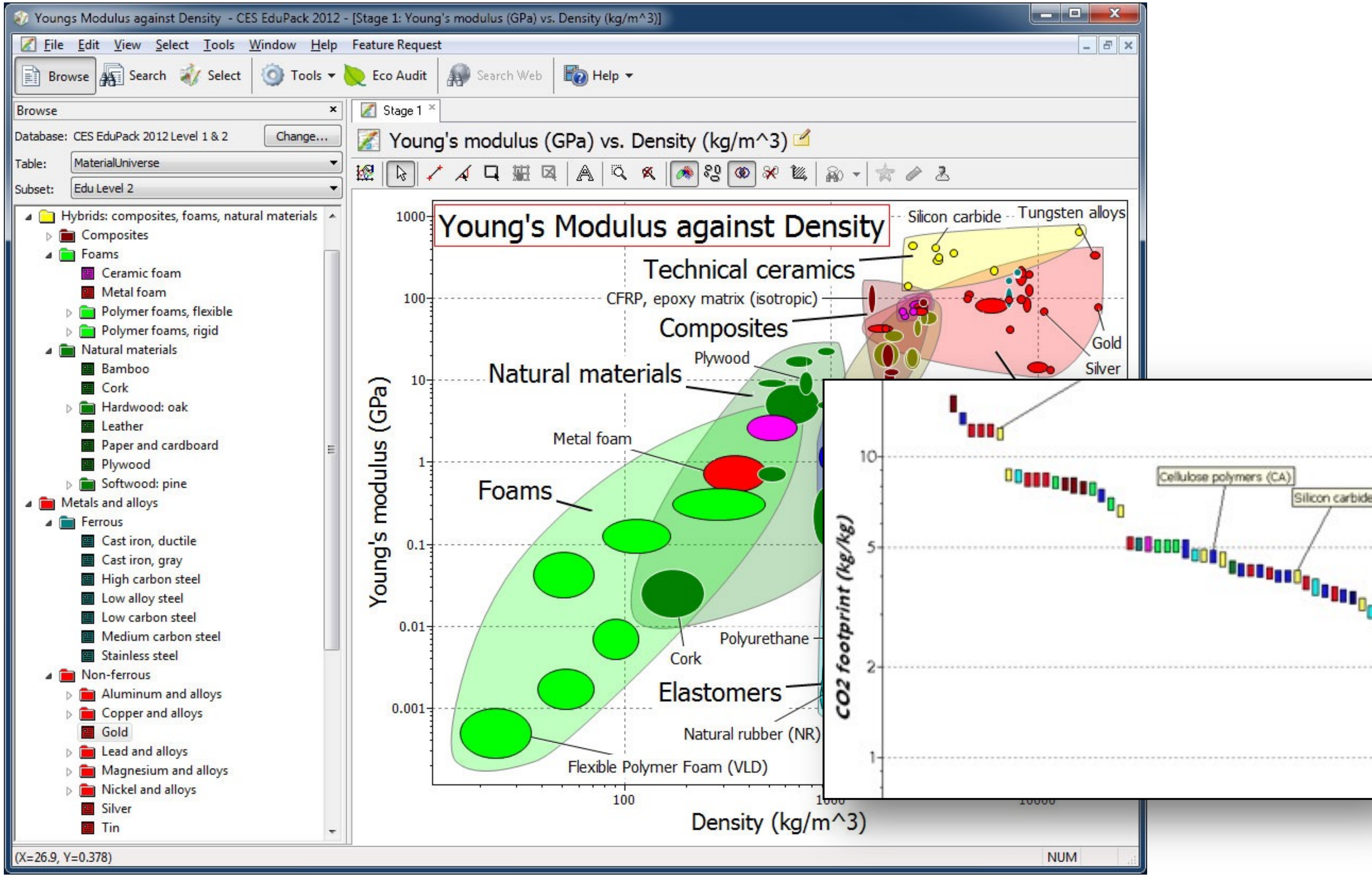
Design guidelines
Standard grade PP is inexpensive, light and ductile but it has low strength. It is more rigid than PE and can be used at higher temperatures. The properties of PP are similar to those of HDPE but it is stiffer and melts at a higher temperature (165 - 170 C). Stiffness and strength can be improved further by reinforcing with glass, chalk or talc. When drawn to fiber PP has exceptional strength and resilience; this, together with its resistance to water, makes it attractive for ropes and fabric. It is more easily molded than PE, has good transparency and can accept a wider, more vivid range of colors. PP is commonly produced as sheet, moldings fibers or it can be foamed. Advances in catalysis promise new co-polymers of PP with more attractive combinations of toughness, stability and ease of processing. Mono-filaments fibers have high abrasion resistance and are almost twice as strong as PE fibers. Multi-filament yarn or rope does not absorb water, will float on water and dyes easily.

Technical notes
The many different grades of polypropylene fall into three basic groups: homopolymers (polypropylene, with a range of molecular weights and thus properties), co-polymers (made by co-Polymerization of propylene with other olefines such as ethylene, butylene or styrene) and composites (polypropylene reinforced with mica, talc, glass powder or fibers) that are stiffer and better able to resist heat than simple polypropylenes.

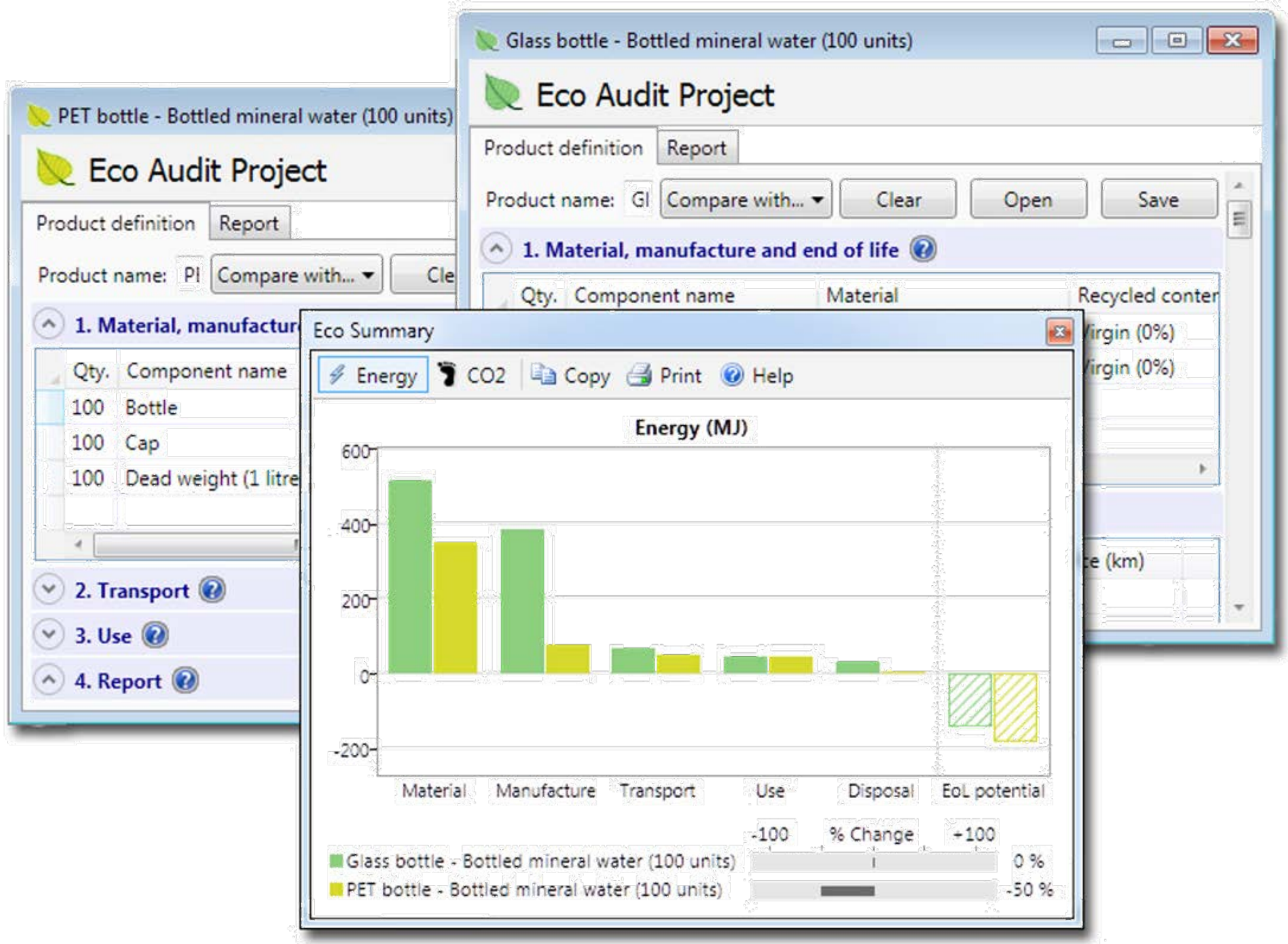
Typical uses

Source: Ashby (2013) CES Edupack tutorial

Granta Edupack interface – Material comparisons:



Granta Edupack interface – Eco-auditing:



Granta Edupack remote use

Due COVID-19 and transfer to online studies, there's currently no access to Aalto computer classes with CES Edupack

Granta Edupack is, hovewer, available to use through Virtual Destop!

https://www.aalto.fi/en/services/vdiaaltofi-how-to-use-aalto-virtual-desktop-infrastructure

…You can also download Granta Edupack from https://download.aalto.fi/ (this works unfortunately only for PC computers, though Mac users could use Bootcamp or emulator to run Windows on Mac)

Sessions 5–7: Assessment and redesign exercise

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Assessment and redesign exercise (sessions 5-7)

Assessment and redesign exercise consists of two parts:

1. **Assessment of sustainability impacts (of product/material)**
2. **Redesign improvements**

Exercise is done independently, assessment followed by redesign;

Final results are communicated on next Tuesday with a poster

(Poster instructions on Thursday!)

Reflection in learning diary after session 7, next week!

Assessment and redesign exercise: (for Thursday session)

In the assessment part of the exercise, you perform a simple assessment on your selected topic (exercise part 1).

For next session (Thu 6.4.):

- Pick a topic for assessment (product/service/system/material)
- Identify main materials, processes, stakeholders
- Identify major sustainability issues and impacts along the life phases
  - *Raw materials production; Manufacturing processes; Transport/logistics; End-of-Life (EoL) options; and/or use phase itself*
- Consider dominant phases and sustainability issues!

For Thursday session

Reading:

***Allwood, J., & Cullen, J. (2010). Sustainable Materials – with Both Eyes Open* (see MyCourses)**

- Chapter 16: Longer life products
- Chapter 17: Reducing final demand

Learning diary entry for this week:

"How comprehensive understanding and knowledge is needed to guide sustainable design action? Reflect on controversies and contradictions from a design perspective."

See you on Thursday!

Thank you!

See you on Thursday…