Aalto University
School of Arts, Design
and Architecture

Eco-Auditing:
Assessing sustainability impacts in design

Spring 2023 / Teaching Period III
Thursdays 12.1., 19.1. & 26.1. (13:15–16:30)

Teacher: Tatu Marttila
12.1.2023

Course information & schedule

Eco-Auditing D (2 ECTS / MUO-E8017)

- **Eco-auditing course** familiarizes the students with **assessing ecological and social impacts** of materials, products and systems
- Thursdays 12.1., 19.1. and 26.1. (13:15–17)
- Sessions held in computer room R102 in Väre building
- **Course readings and slides in MyCourses:** https://mycourses.aalto.fi/course/view.php?id=36063
- Students will use **Granta EduPack software** (on Aalto computers) to support material selection, assessment & design
- Outcomes include a **small eco-audit exercise** and **report**
- The course is open to all Aalto students (master-level)

Course schedule

First contact day: Thursday 12.1. (13:15–16:30):

- Basics of lifecycle design and material selection
- Familiarizing with Edupack material selection tools
- Introducing project ideas

Second day: Thursday 19.1. (13:15–16:30):

- Basics of eco-auditing and lifecycle impact assessment
- Familiarizing with Edupack eco-auditing tool
- Project work status (& tutoring for project work)

Third day: Thursday 26.1. (13:15–16:30):

- Project report guidelines & examples
- Project work status

Final project work reports

Final reports on project work due 20.2. (period III end):

- Around 5-7 pages (or more) PDF document with:
  - Description of the project idea
  - Assessment of focus materials (system boundaries, material inventory, life phases)
  - Description of the eco-auditing process/comparison
  - Reflection on results
- Can be essay-like document or presentation type
- Some example project reports presented on session 3 (26.1.)
- Upload to course MyCourses after course!

Granta Edupack program

You can also have a remote access to Granta Edupack program:

1. Use Virtual Desktop to access Granta Edupack on Aalto online from your own laptop, this is easiest way to go but might be slow…
   See: https://www.aalto.fi/en/services/vdiaaltofi-how-to-use-aalto-virtual-desktop-infrastructure

2. 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).

12.1.
Eco-Auditing course:

Ecodesign, life-cycle design and material selection strategies

Material crisis

Natural resources

"Natural resources are materials, energy, and their attributes that are derived from the Earth and are useful or of value to the maintenance and improvement of the quality of human life."

-Encyclopedia of life support systems

Sustainable development is considering "ecosystem services" and "natural capital" as shared commodities, even across generations

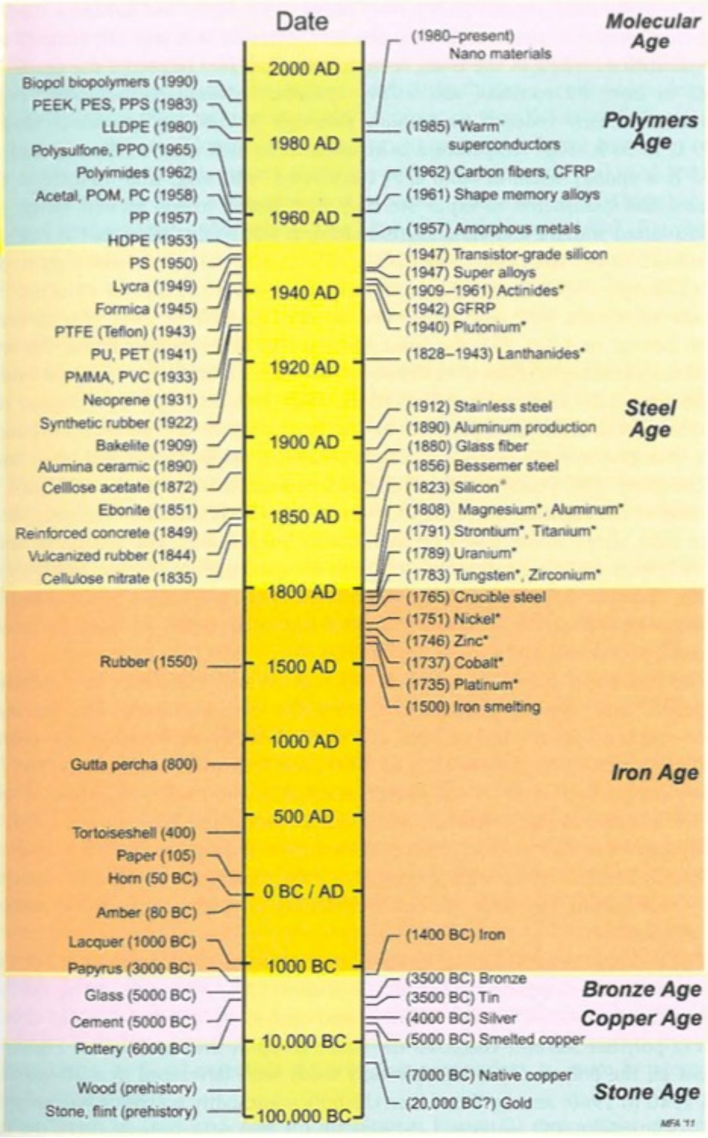
Renewable & non-renewable materials

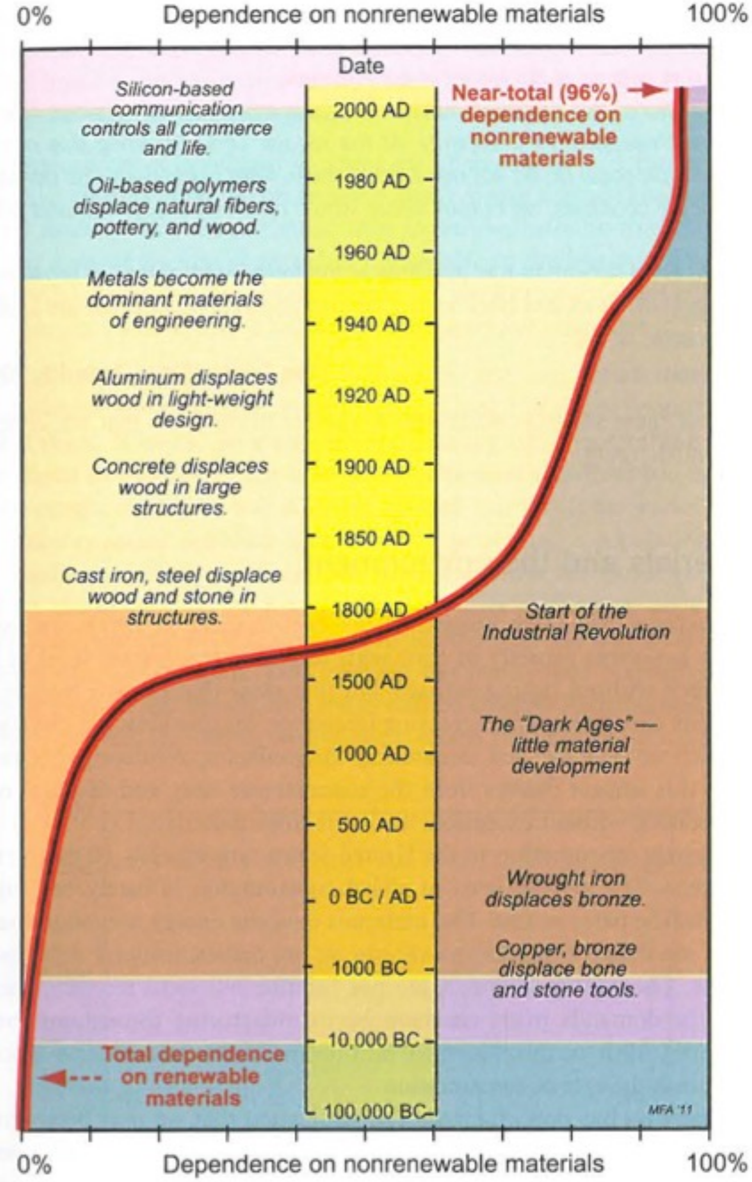
Renewable materials:

- "refer to those resources that originate from storage of energy from sun by living organisms including plants, animals and humans. Providing that sufficient water, nutrients and sunshine are available, renewable resources can be grown in continuous cycles"
- resources are rapidly renewable if the crop takes under three years to regrow,
- annually renewable resources (the crops which grow and are harvested in one year)

Non-renewable materials are those that do not renew at those speeds. Thus, also e.g. peat can be considered non-renewable.

Our material dependency:





Facing an era of peak-everything:

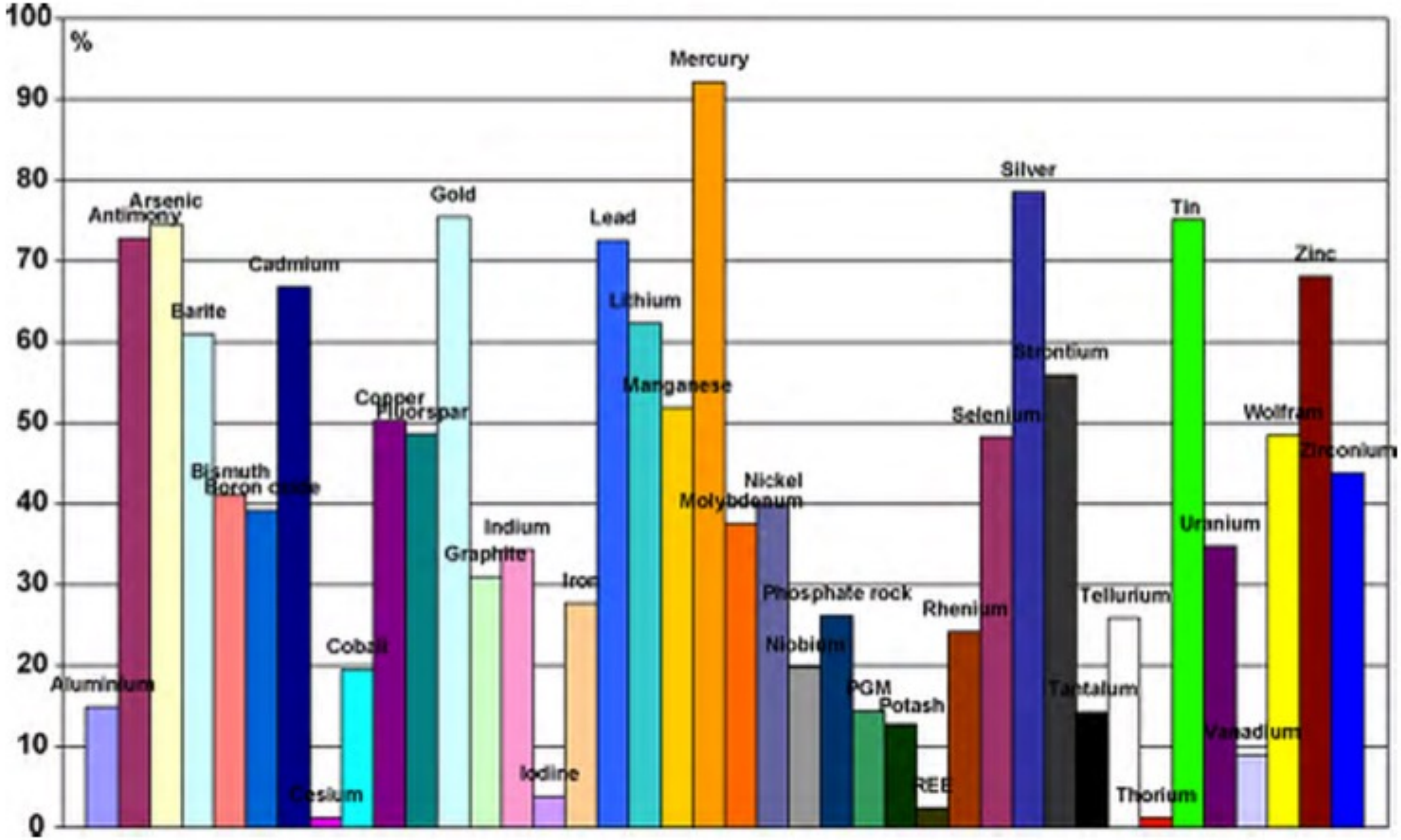
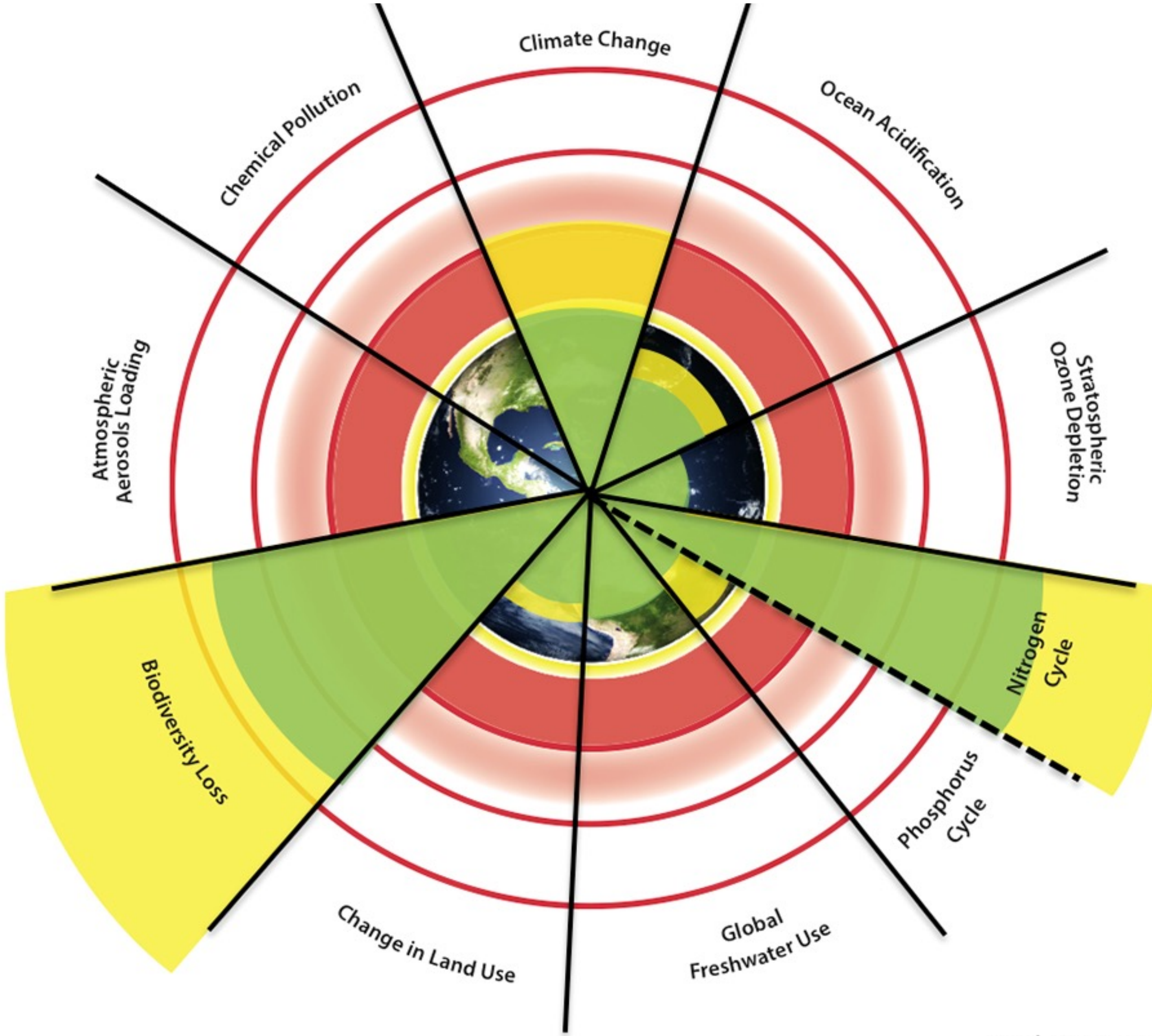


Fig. 3. Depletion degree in % of the main non-fuel mineral commodity reserves.

Facing planetary boundaries:



Rockstrom et al., 2009

Materials, design & sustainability

‘Lock-in’ of environmental impacts

The environmental (and social) performance is largely established early in the product development cycle, when critical decisions are made on key product attributes

Design for the whole life-cycle!

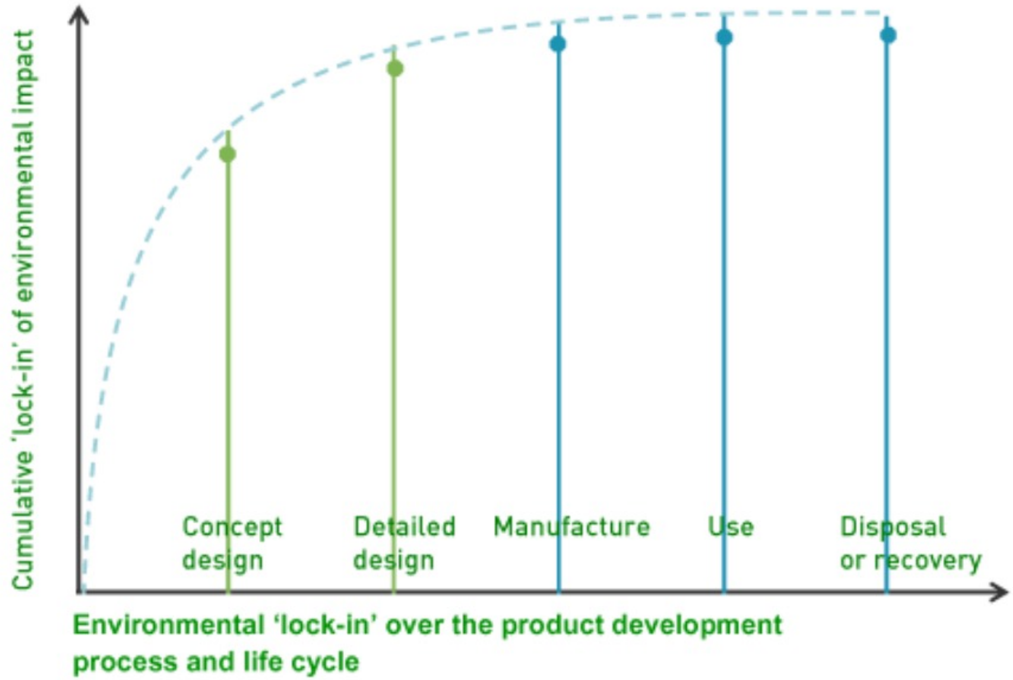


Figure 3 - Early design stages define key attributes that ultimately determine the environmental performance of a product throughout its life cycle. Adapted from "Design + Environment – a Global Guide to Designing Greener Goods", Lewis, H., Gertsakis, J., Grant, T., Morelli, N. & Sweatman, A., New York: Greenleaf Publishing 2001.

Source: sustainableminds.com/learning-center/ecodesign-and-lca/ecodesign-overview

Global material sources

Relatively simple products can have parts from all around the world. Sometimes transporting goods is justifiable (complex products), but many times it's not (food from abroad or other simple products).

Some materials are more problematic than others. A lot of fossil fuels is used for transport of materials, components, and products.

Sustainable design solutions acknowledge these dependencies. Material flows within a product or a system should be somehow identified.

See e.g. Sourcemap
https://www.open.sourcemap.com/

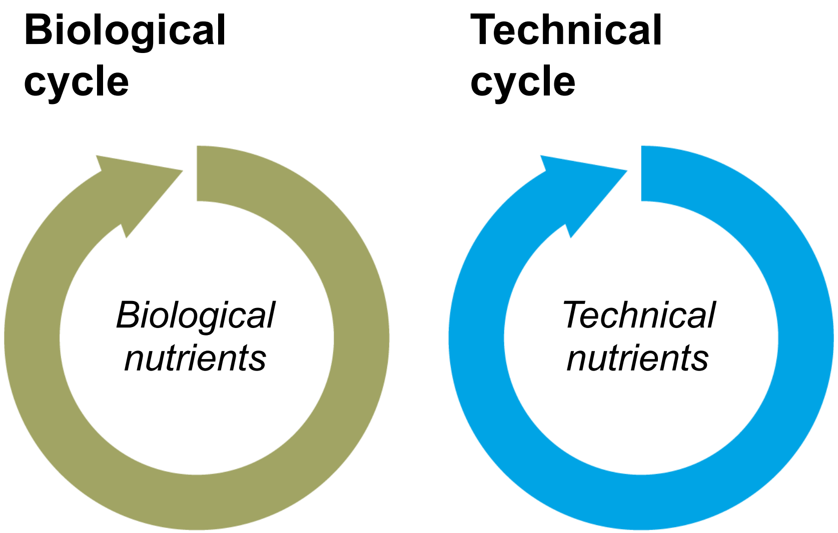
‘Metabolisms’ of materials

<u>Different "metabolisms”:</u>

- Biological cycle
- Technical cycle

These should not cross-contaminate

“Cradle-to-cradle” life-cycle design:



Source: McDonough, W. and M. Braungart (2001) ‘The Next Industrial Revolution’ in Charter, M. & U. Tischner (eds.) *Sustainable solutions: developing products and services for the future)*

Closing the loops for material flows

<u>Correct cycling of materials:</u>

Organic waste cannot be tossed to landfill, where it cannot build new soil. Depositing synthetic materials and chemicals in natural systems, on the other hand, harms environment.

Technical nutrients should be designed to go back into the technical cycle in such a manner that it allows materials to retain their quality, and that they are not contaminating the biological cycle.

Source: McDonough, W. and M. Braungart (2001) ‘The Next Industrial Revolution’ in Charter, M. & U. Tischner (eds.) *Sustainable solutions: developing products and services for the future)*

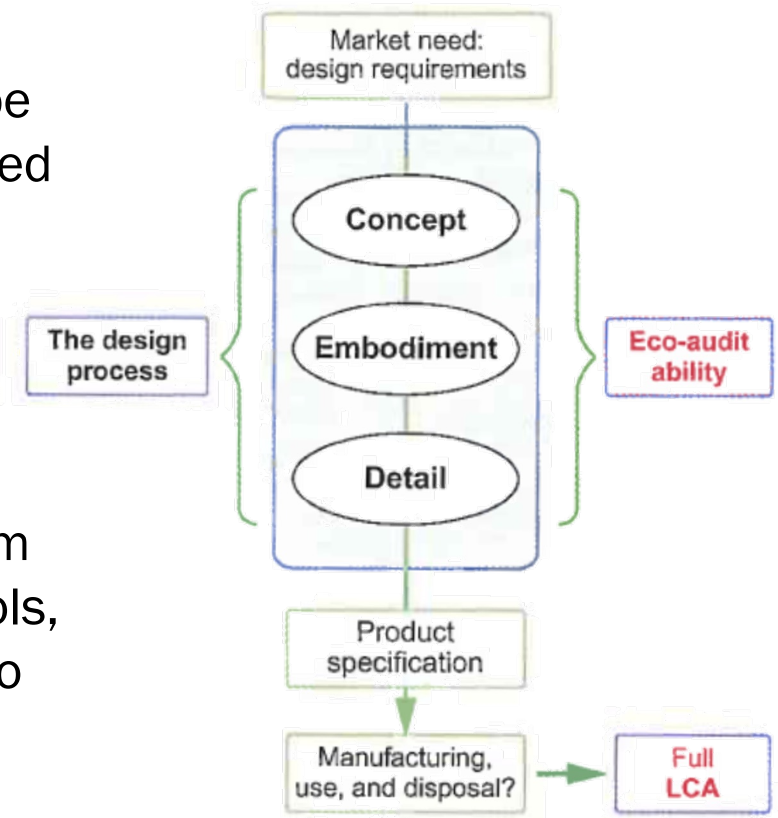
Material impacts and life-cycle design & assessment (LCA)

Life-cycle design & assessment (LCA)

Sustainable design considers product's whole life. It should also include (some type of) assessment of the impacts of its involved material use and production processes, in each different phase of product-life.

<u>One mainly used approach in ecodesign is life-cycle assessment (LCA)</u>

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.



LCA involves an analysis of system boundaries:

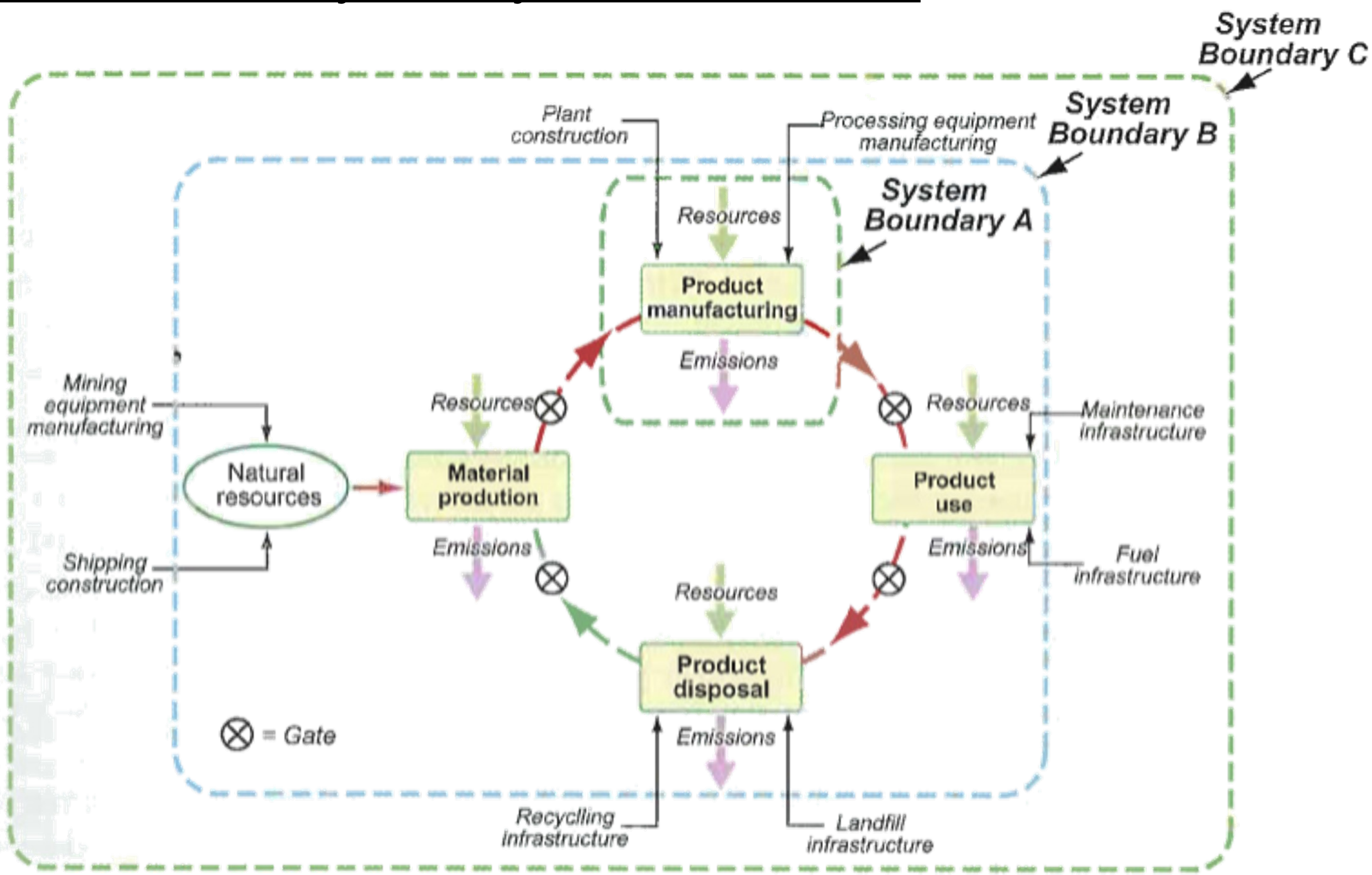


FIGURE 3.3 *LCA system boundaries with the flows of resources and emissions across them. System Boundary A encloses a single phase of the lifecycle. System Boundary B encloses the direct inputs and emissions of the entire life. It does not make sense to place the system boundary at C, which has no well-defined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

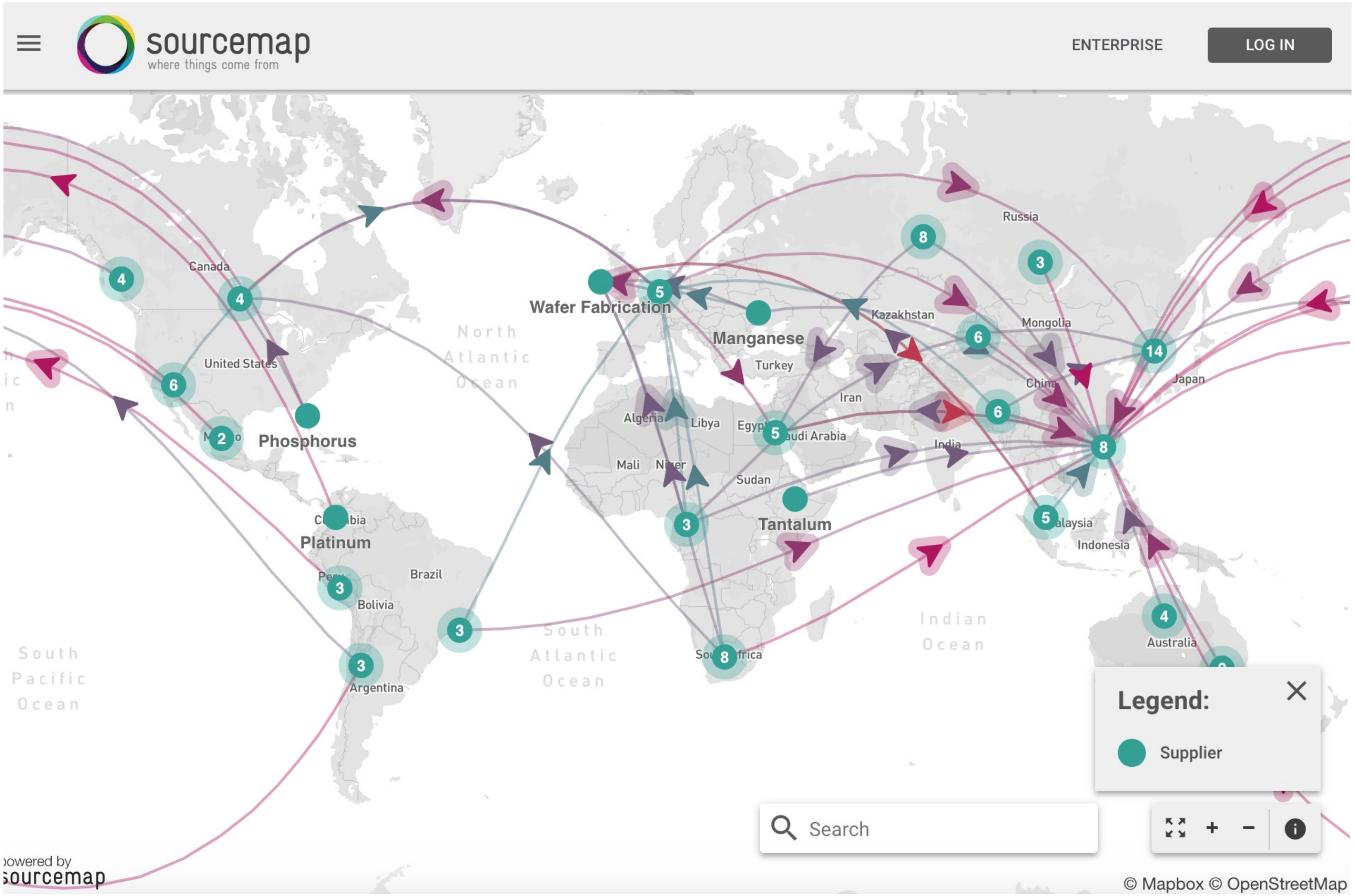
Source: Ashby, M. (2012) Materials and the Environment: Eco-Informed Material Choice

LCA involves inventory of components, materials & processes:

Table 14: Composition ASUS UL50Ag

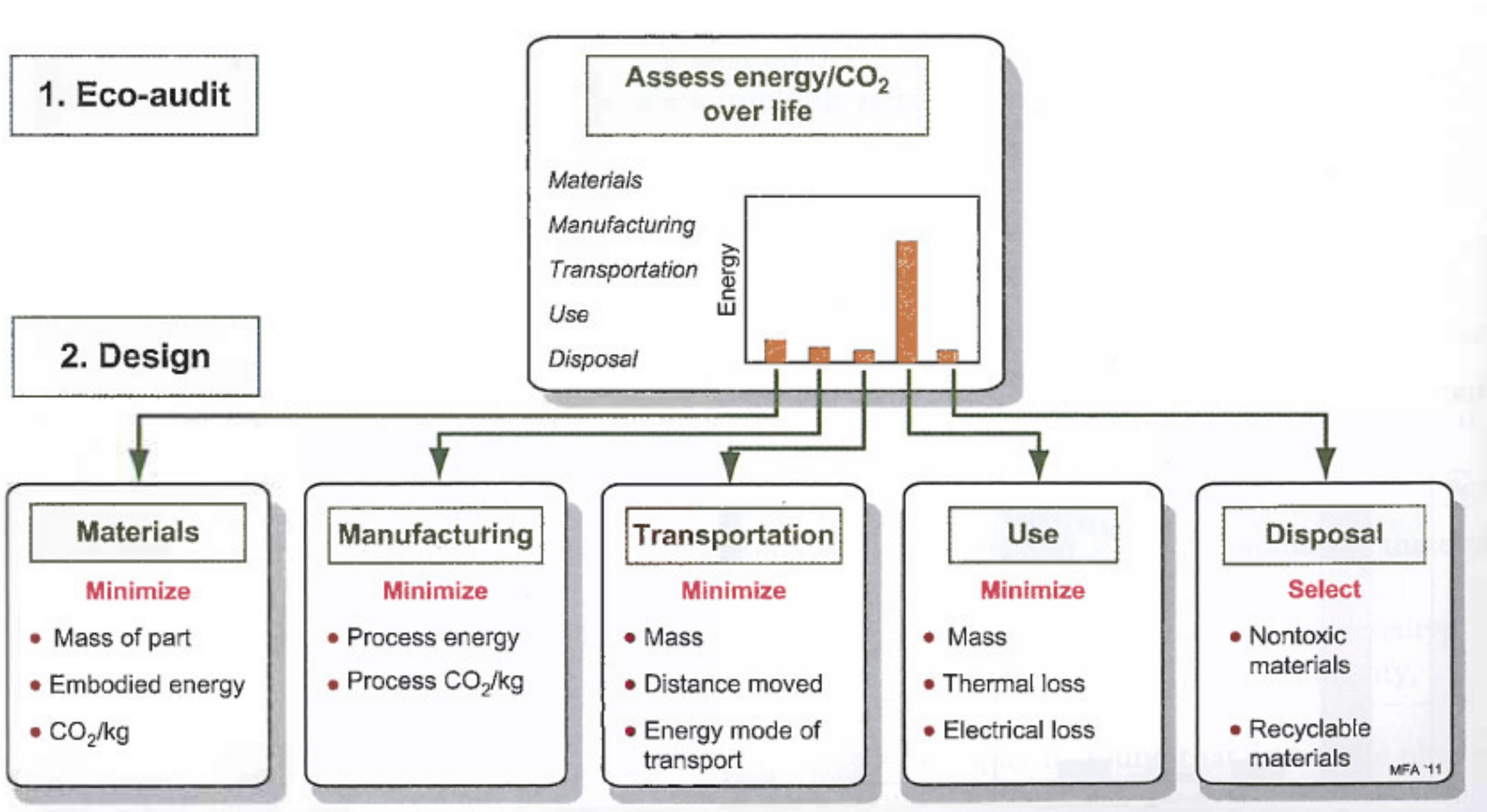
Component	Weight	Material	Basic ecoinvent process
Mainboard	204.2g		Printed wiring board, mounted, Laptop PC mainboard, Pb free, at plant/GLO
HDD	114.8g		HDD, laptop computer, at plant/GLO
RAM	2*7.9g		Integrated circuit, IC, memory type, at plant/GLO
Display	731.0g		LCD module, at plant/GLO
Case (including the back of the display)	906.0g	ABS,PC, and Aluminium	Acrylonitrile-butadiene-styrene copolymer, ABS, at plant RER; Polycarbonate, at plant/RER; Aluminium, primary, at plant/RER
Keyboard	123.8g		Keyboard, standard version, at plant/GLO
Battery pack	440.0g		Battery, LiIo, rechargeable, prismatic, at plant/GLO
Drive	135.8g		CD-ROM/DVD-ROM drive, laptop computer, at plant/GLO
Fan	27.7g		Fan, at plant/GLO
Power adapter	362.0g		Power adapter, for laptop, at plant/GLO
Product packaging			
Card board	739.0g	Corrugated board	Corrugated board, fresh fibre, single wall, at plant/RER
Handle	14.8g	HDPE	Polyethylene, HDPE, granulate, at plant/RER
Mail packaging			
Card board	446.0g	Corrugated board	Corrugated board, fresh fibre, single wall, at plant/RER
Filling	4*5.8g	HDPE	Polyethylene, HDPE, granulate, at plant/RER

LCA with social impact assessment also looks at material chains:



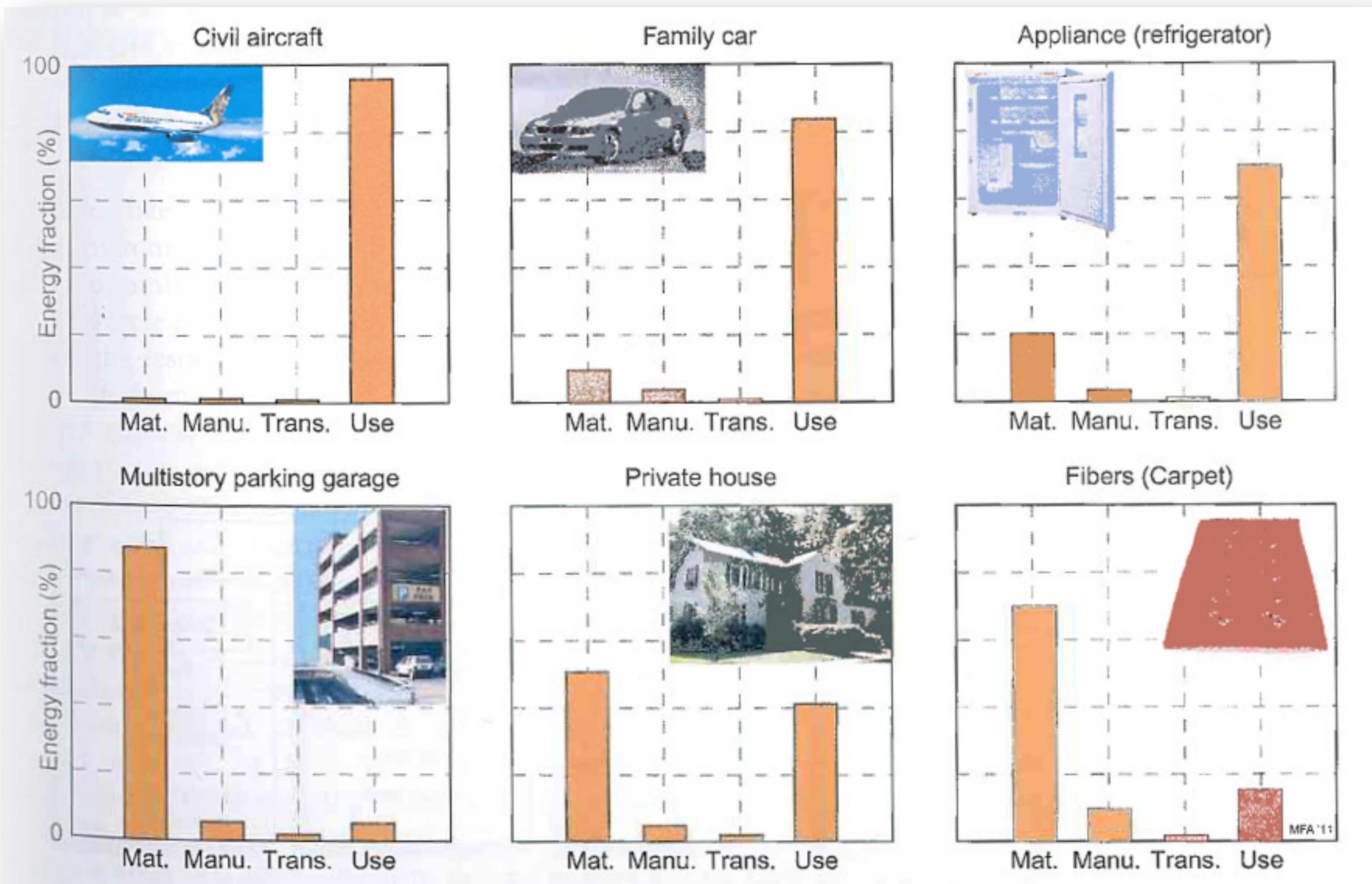
Source: https://open.sourcemap.com/maps/57d0d127dd3780d6272b3f8c

LCA involves analysis of environmental impacts throughout all the phases of product-life:



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

Products have impacts in different phases of life:



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

Life-cycle assessment – process:

Life-cycle assessment (LCA) is carried out in the following four phases:

1) Definition of goal and scope, the aims for improvement, and the system with its boundaries;
2) Creation of an inventory of the inputs and outputs in selected dimensions depending on LCA approach or method used;
3) Assessment of life cycle impacts, which include the estimation of effects of studied inventory;
4) Interpretation that is reflecting three other phases continuously.

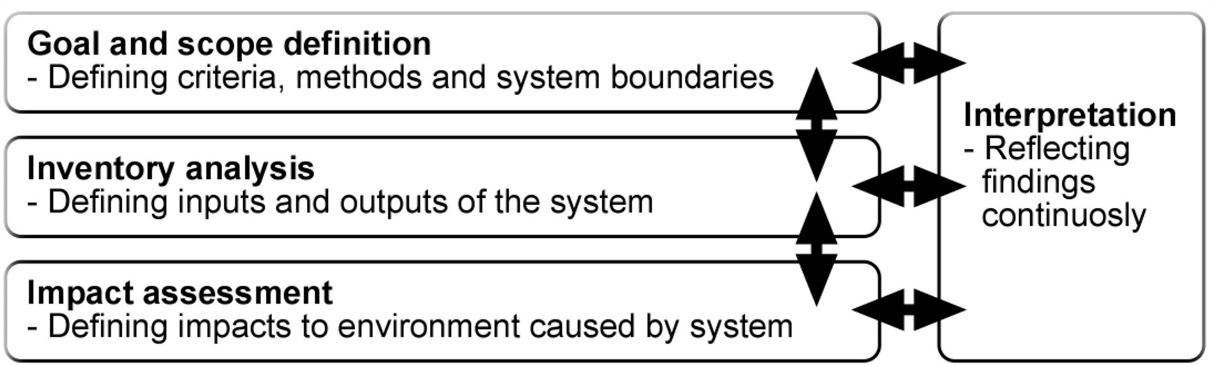


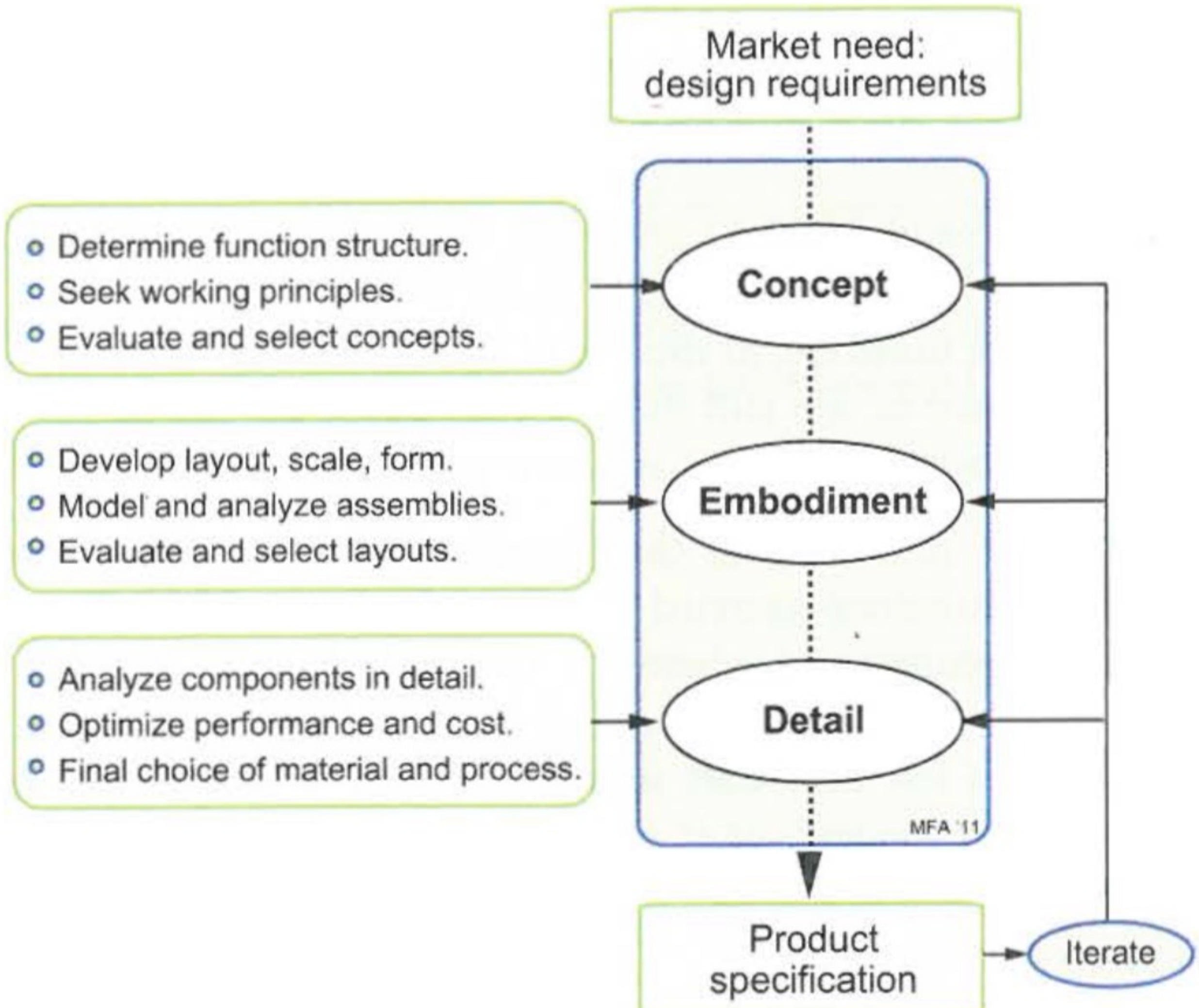
Figure 2. The process of LCA (according to ISO 14040 and ISO 14044).

LCA supported design process, why is it done:

Why do impact assessment? Some possible answers:

- To guide the design of more environmentally friendly products
- To demonstrate that you are an environmentally responsible manufacturer
- To allow the public to form their own judgment about your products
- To demonstrate that your products are greener than those of your competitor
- To be able to claim conformity to standards such as ISO 14040 and PAS 2050 (described later)
- Because the enterprise to which you are a supplier or subcontractor requires that you do so so that they can claim conformity to standards.

LCA supported design process, aiming to mitigate impacts:



Ecodesign as a design strategy

Simplified life-cycle assessment (SLCA)

The methodologies used in LCA process can be divided in approaches utilizing quantitative, semi-quantitative or qualitative life-cycle assessment methods and data. (Wenzel, H. 1998)

Simplified, or streamlined LCA (SLCA) is divided also in semi-quantitative and qualitative strategies, including input-output tools and matrix approaches.

Commonly, SLCA tools often emphasize general values over specific numbers from a specific assessment. Many of them can also combine quantitative and qualitative aspects

Example – META matrix:

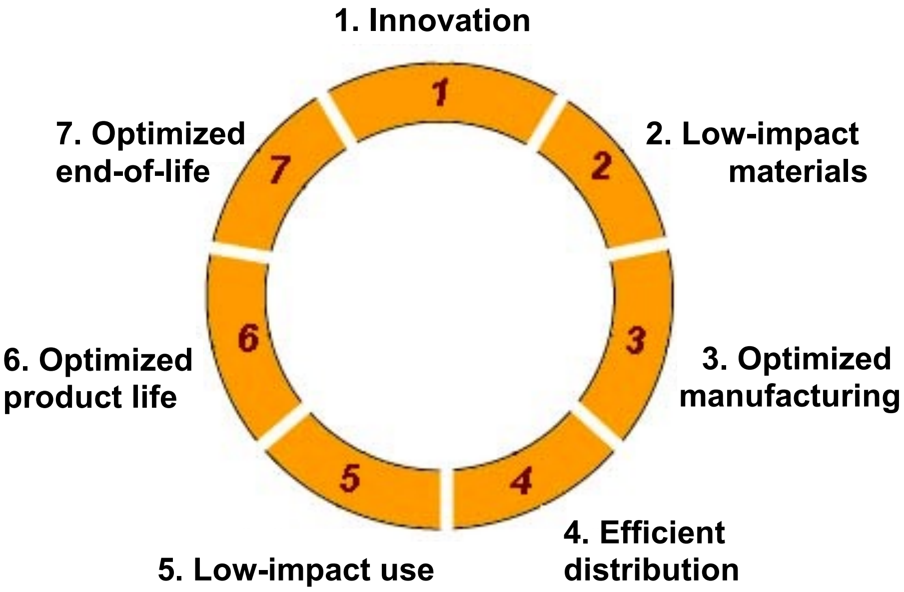
Impact category	Material production	Manufac-turing	Use-phase	End-life	Transport
M-Materials					
E-Energy					
T-Toxicity					
A-Socio-cultural					

Eco-design strategy wheel

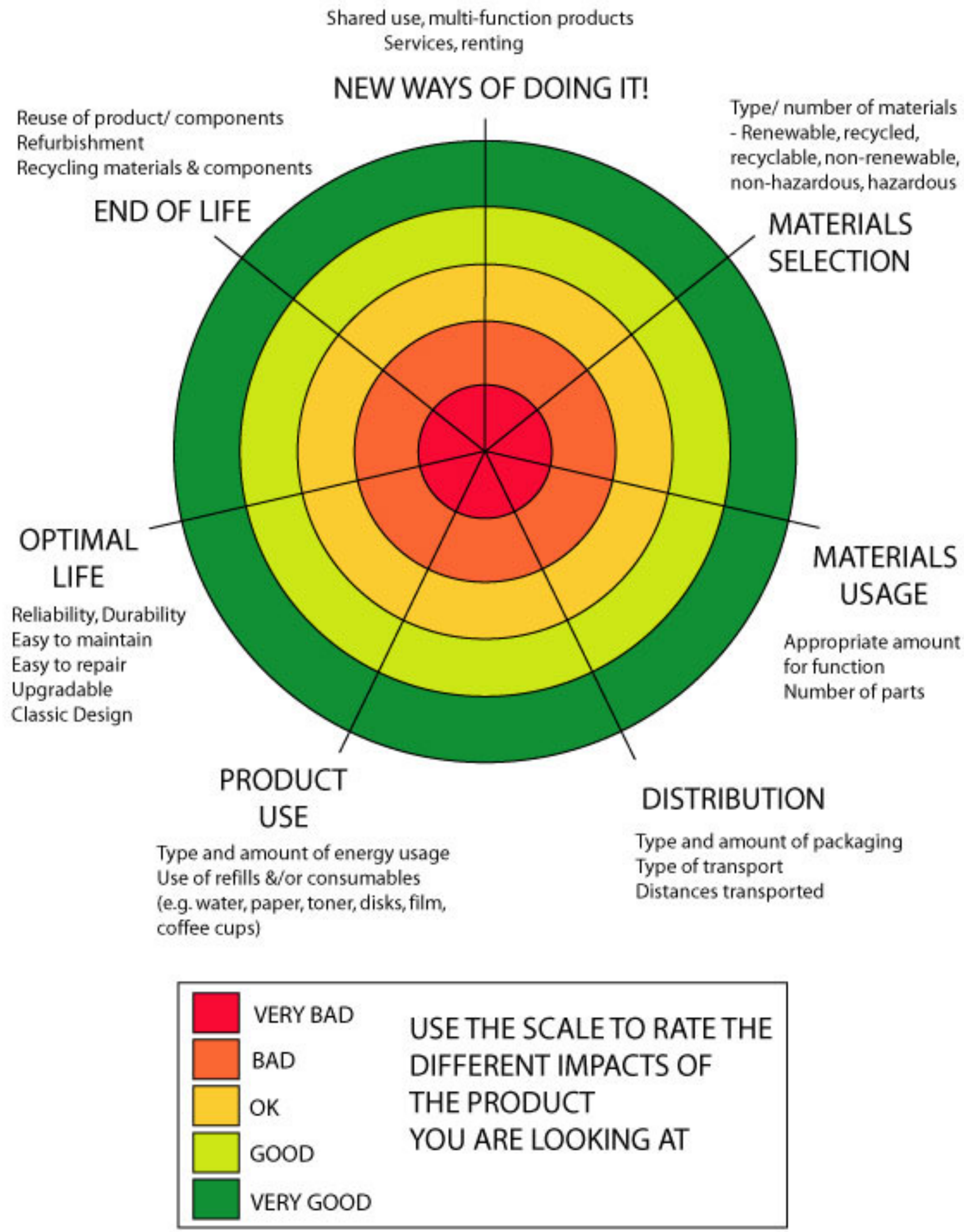
1. Define the product idea, product concept or existing product that will be analyzed. (evaluate existing system or your concept)

2. Systematically score the product on each dimension of the strategy wheel, linked to life phases of the product.

3. Consider the optimization options for each of the dimensions, paying special attention to those where the current design scores badly.



Ecodesign strategy wheel by TU Delft


Shared use, multi-function products
Services, renting
NEW WAYS OF DOING IT!
Type/ number of materials
- Renewable, recycled, recyclable, non-renewable, non-hazardous, hazardous
MATERIALS SELECTION
MATERIALS USAGE
Appropriate amount for function
Number of parts
DISTRIBUTION
Type and amount of packaging
Type of transport
Distances transported
PRODUCT USE
Type and amount of energy usage
Use of refills &/or consumables (e.g. water, paper, toner, disks, film, coffee cups)
OPTIMAL LIFE
Reliability, Durability
Easy to maintain
Easy to repair
Upgradable
Classic Design
END OF LIFE
Reuse of product/ components
Refurbishment
Recycling materials & components
VERY BAD
BAD
OK
GOOD
VERY GOOD
USE THE SCALE TO RATE THE DIFFERENT IMPACTS OF THE PRODUCT YOU ARE LOOKING AT

Design for:

1. Innovation

- Rethink how to provide the benefit
- Serve needs provided by associated products
- Anticipate technological change and build in flexibility
- Provide product as service
- Share among more users
- Design to mimic nature
- Use living organisms in product

Design for:

2. Low-impact materials

- Avoid materials that damage human health, ecological health, or deplete resources
- Use minimal materials
- Use renewable resources
- Use waste by-products
- Use thoroughly tested materials
- Use recycled or reused materials

Design for:

3. Optimized manufacturing

- Design for ease of production quality control
- Minimize manufacturing waste
- Minimize energy in production
- Minimize number of production methods and operations
- Minimize number of components/materials

Design for:

4. Efficient distribution

- Reduce product and packaging waste
- Use reusable or recyclable packaging
- Use an efficient transport system
- Use local production and assembly

Design for:

5. Low-impact use

- Minimize emissions/integrate cleaner or renewable energy sources
- Reduce energy inefficiencies
- Reduce water use inefficiencies
- Reduce material use inefficiencies

Design for:

6. Optimized product lifetime

- Build in user's desire to care for product long term
- Design for take-back programmes
- Build in durability
- Design for maintenance and easy repair
- Design for upgrades
- Design for second life with different function
- Create timeless look or fashion

Design for:

7. Optimized end-of-life

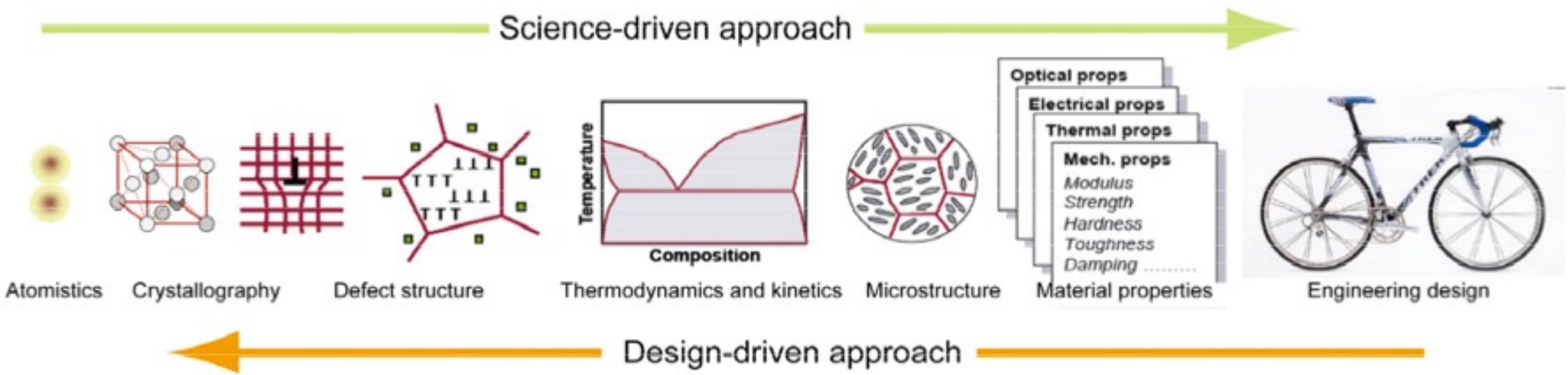
- Integrate methods for product collection
- Provide for ease of disassembly
- Provide for recycling or downcycling
- Design reuse, or ‘next life of product’
- Provide for reuse of components
- Provide ability to biodegrade
- Provide for safe disposal

Granta Edupack program

Approaching material science

Two main approaches in teaching material sciences: Science-driven & design-driven

Design-driven begins with specification of design requirements and translation into material choices, and includes their impact assessment



Source: Edupack 2009 Manual

Material science & design

Design-driven approach has its main focus on material selection and impact assessment.

Specification of design requirements and translation into material choices:

- General properties (price, mass, density)
- Physical properties (strength, insulation, etc.)

Assessing impacts of materials and processes:

- Impacts of production (embodied energy, CO_2 footprint, etc.)
- Impacts of use & end-of-life (scenarios)
- Social hotspots & impacts (demographic data)

Source: Edupack 2009 Manual

CES 2013 EDUPACK

The world-leading teaching resource for materials in engineering, science, processing, and design

Granta Edupack program

Granta’s Edupack Tool (previously CES Edupack, 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 find information and compare different materials and to assist in material selection.

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

On Aalto computers!

Information dimensions in Edupack

In the Edupack database there are several datasheets, regarding:

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

Legislation & regulations
- Advisory organizations (mostly UK, only few)
- Asian directives (China REACH & RoHS)
- Environmental taxes (some general like carbon, fuel, landfill etc.)
- EU directives & regulations (a lot…)
- International agreements & protocols (e.g. UNCSD)
- Standards (ISO)
- U.S. environmental legislation

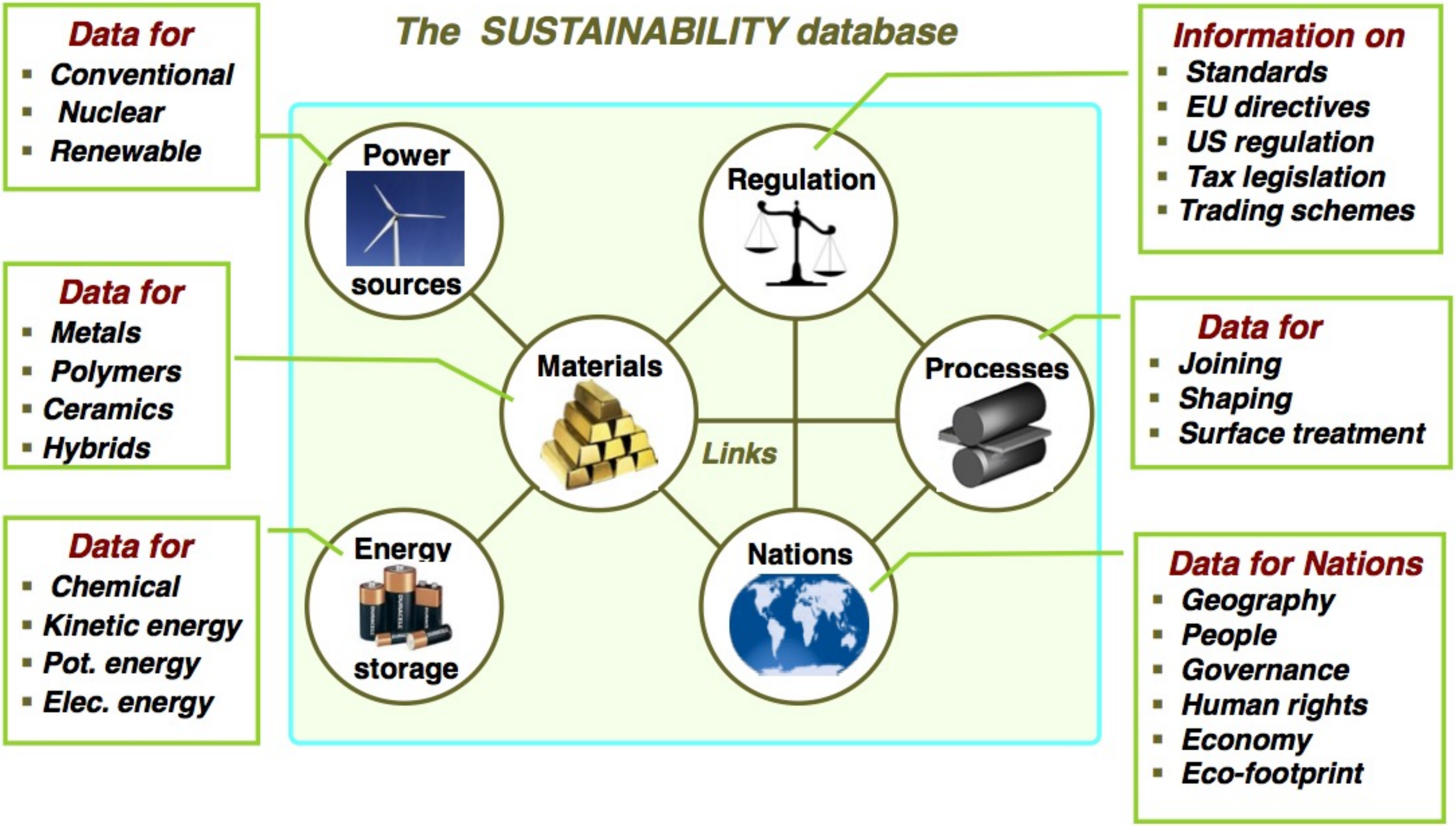
Material Universe
- Ceramics and glasses (21 materials on level 2)
- Hybrids: composites, foams, natural materials (22 on lvl 2)
- Metals & alloys (ferrous & non-ferrous; 28)
- Polymers & elastomers (29)

Process Universe
- Joining, shaping & surface treatment

Nations of The World
- People, education, human rights & governance, economy & development, health, energy & environment

Producers
- Selected examples, mostly UK or Europe

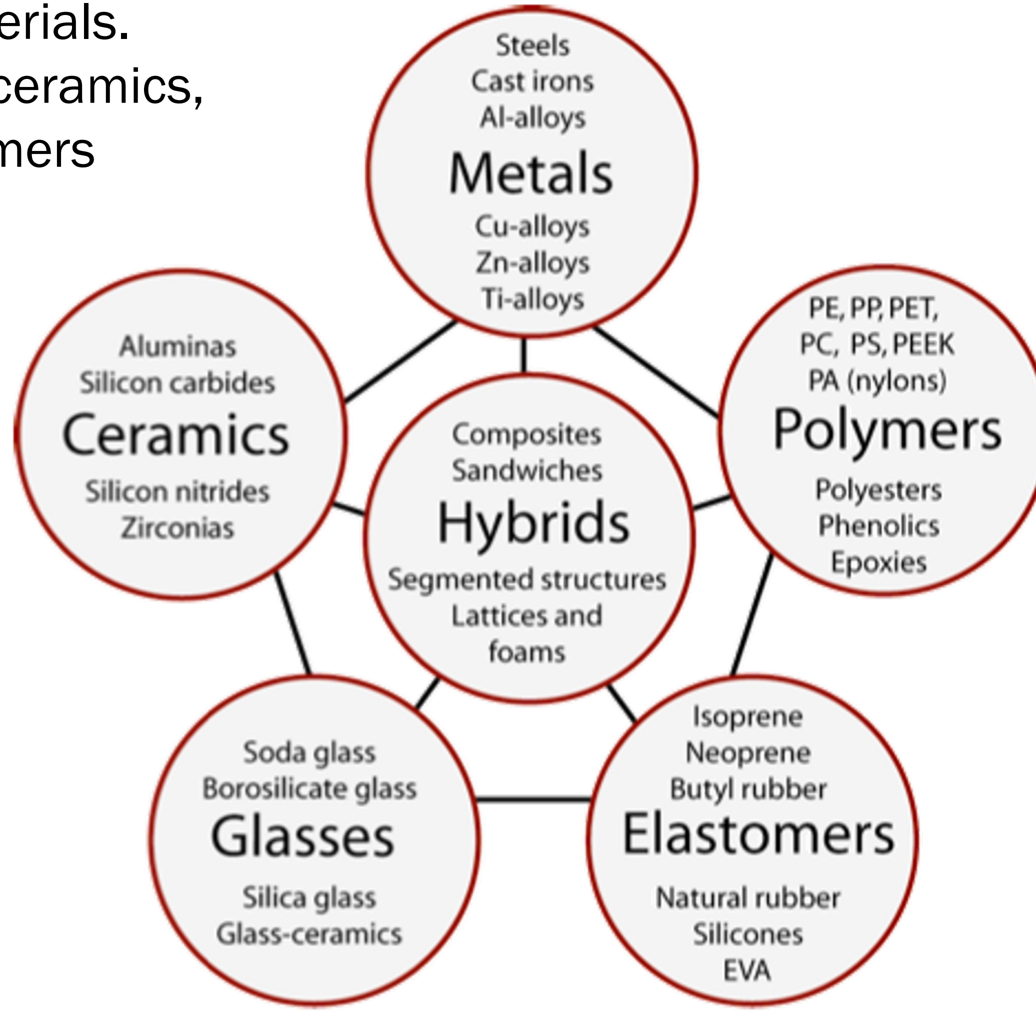
Data to assist sustainable design process:



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

Material Universe and 'families':

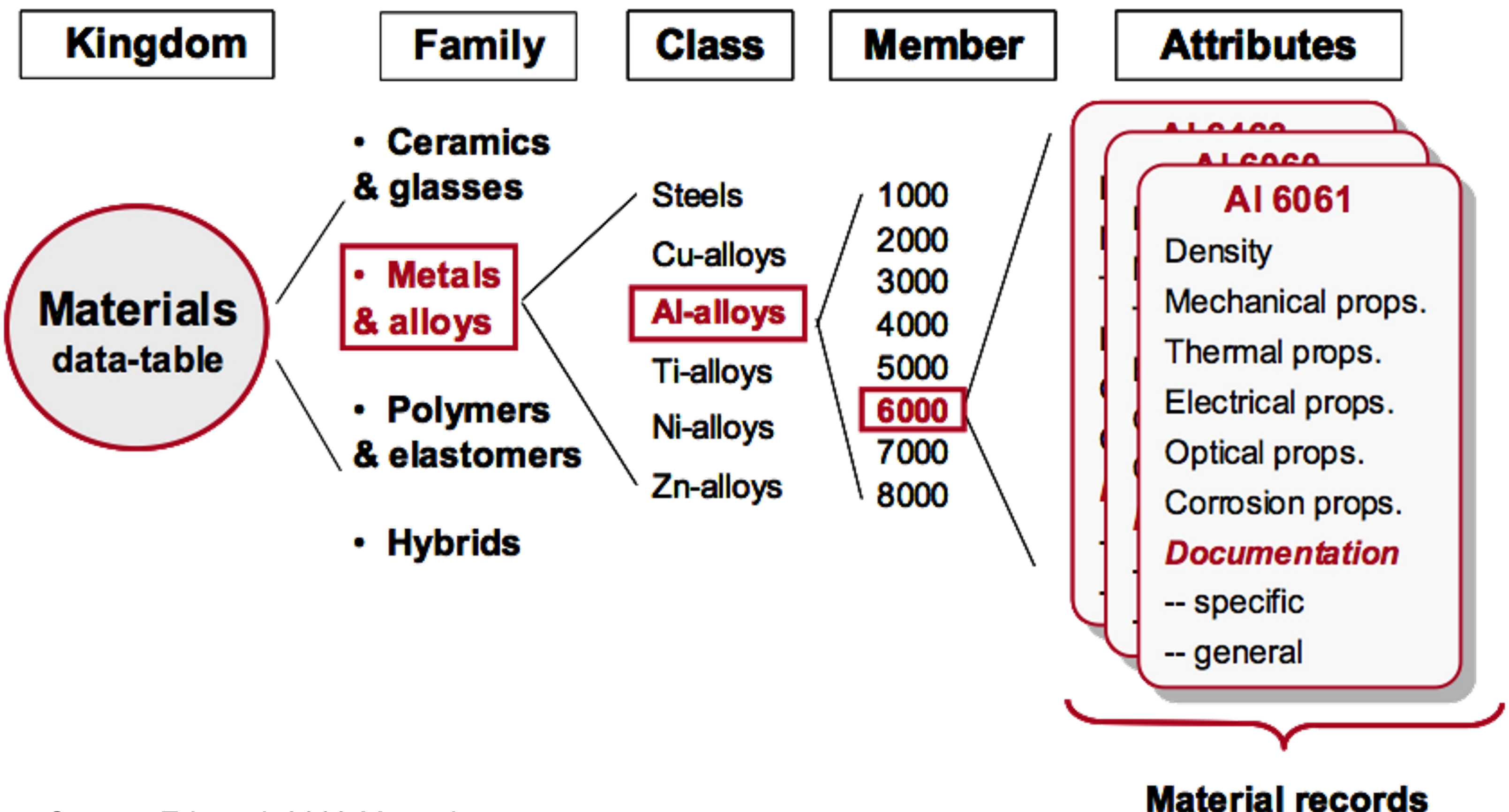
The menu of engineering materials.
The basic families of metals, ceramics, glasses, polymers and elastomers can be combined in various geometries to create hybrids.



Source: Ashby & Cebon (2007) Teaching Engineering Materials

Taxonomies in Material Universe datatables:

A hierarchical structure for process classification, ending with a schematic of a record.



Source: Edupack 2009 Manual

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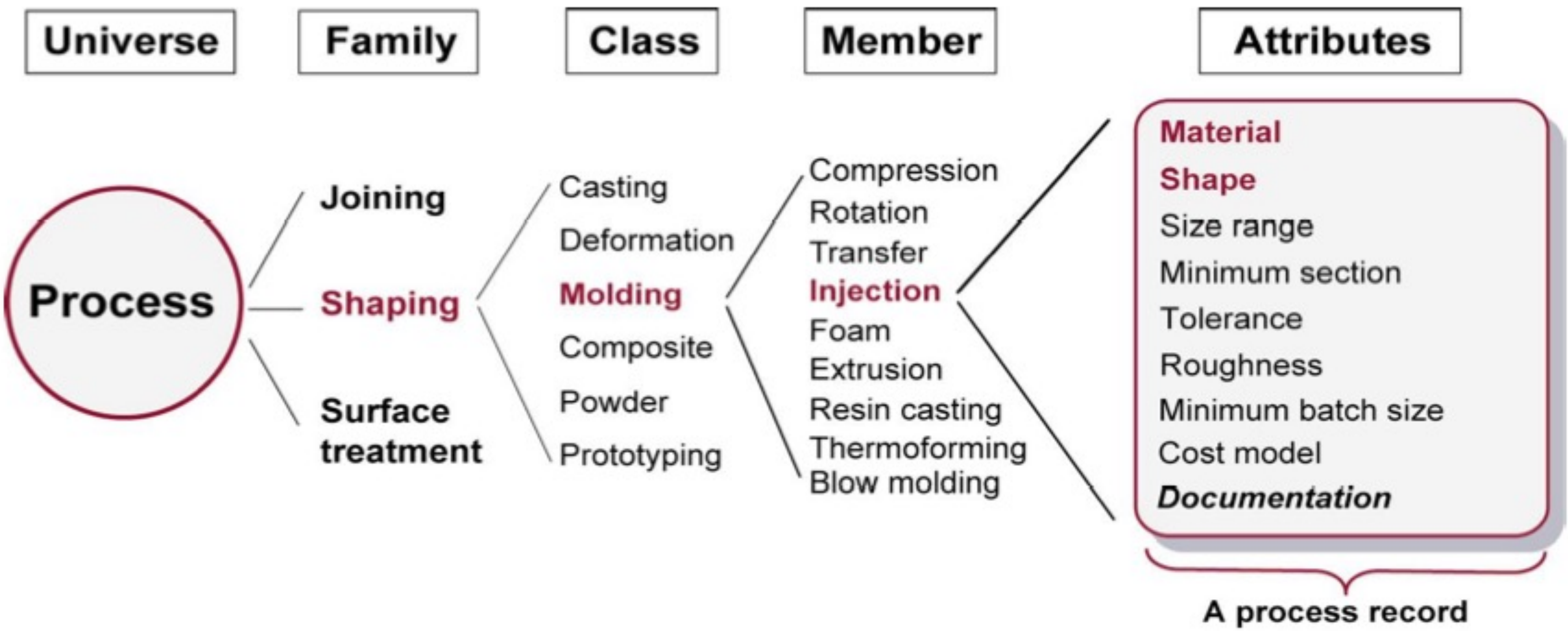
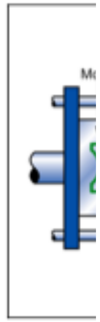


Source: Ashby & Cebon (2007) Teaching Engineering Materials

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 witl 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 temperat 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

5
PP

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

Science notes:

Age-hardening wrought Al-alloys

Description. The high-strength alu…
alloys rely on age-hardening: a sequen…
heat treatment steps that causes the
precipitation of a nano-scale dispersion
intermetallics that impede dislocation m…
and impart strength.

General properties
Density
Price

Mechanical properties
Young's modulus
Yield strength (elastic limit)
Tensile strength
Elongation
Fatigue strength at 10^7 cycles
Fracture toughness

Thermal properties
Melting point
Maximum service temperature
Thermal conductivity
Thermal expansion coefficient

Electrical properties
Electrical resistivity 3.8 -

Young's modulus

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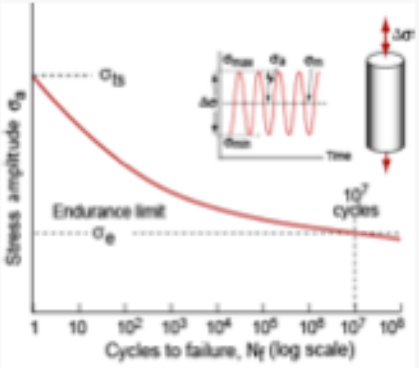
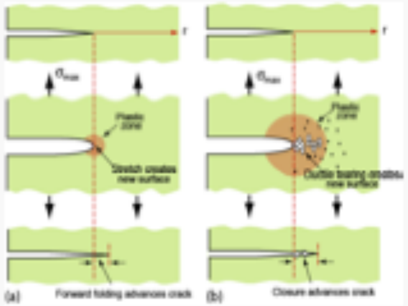
Fatigue strength at 10^7 cycles

Definitions and measurement.
Material subjected to repeated stress cycles may fail even when the peak stress is well below the tensile strength, or even below that for yield. Fatigue data are measured and presented as curves, where $\Delta\sigma$ is the range over which the stress varies and N_f is the number of cycles to failure………



How do fatigue cracks propagate?
Holes, change of section, cracks, and surface scratches concentrate stress so that, even when the sample as a whole remains elastic (the "high-cycle" regime), local plasticity occurs. The damage this creates accumulates, finally developing into a tiny crack. The crack propagates in the way shown on the left of Figure 2. ……….



Two main processes with Edupack

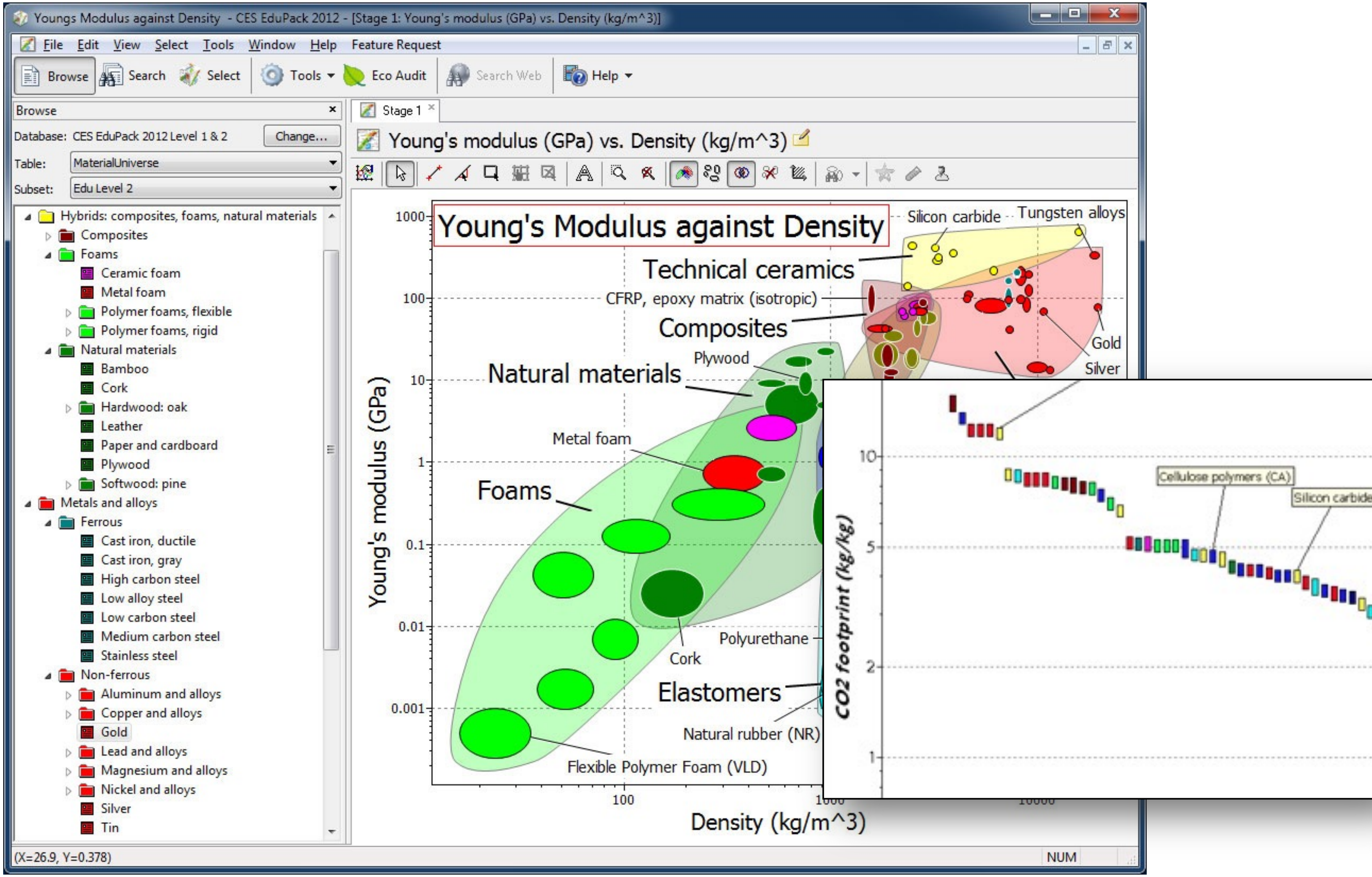
Materials selection:

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

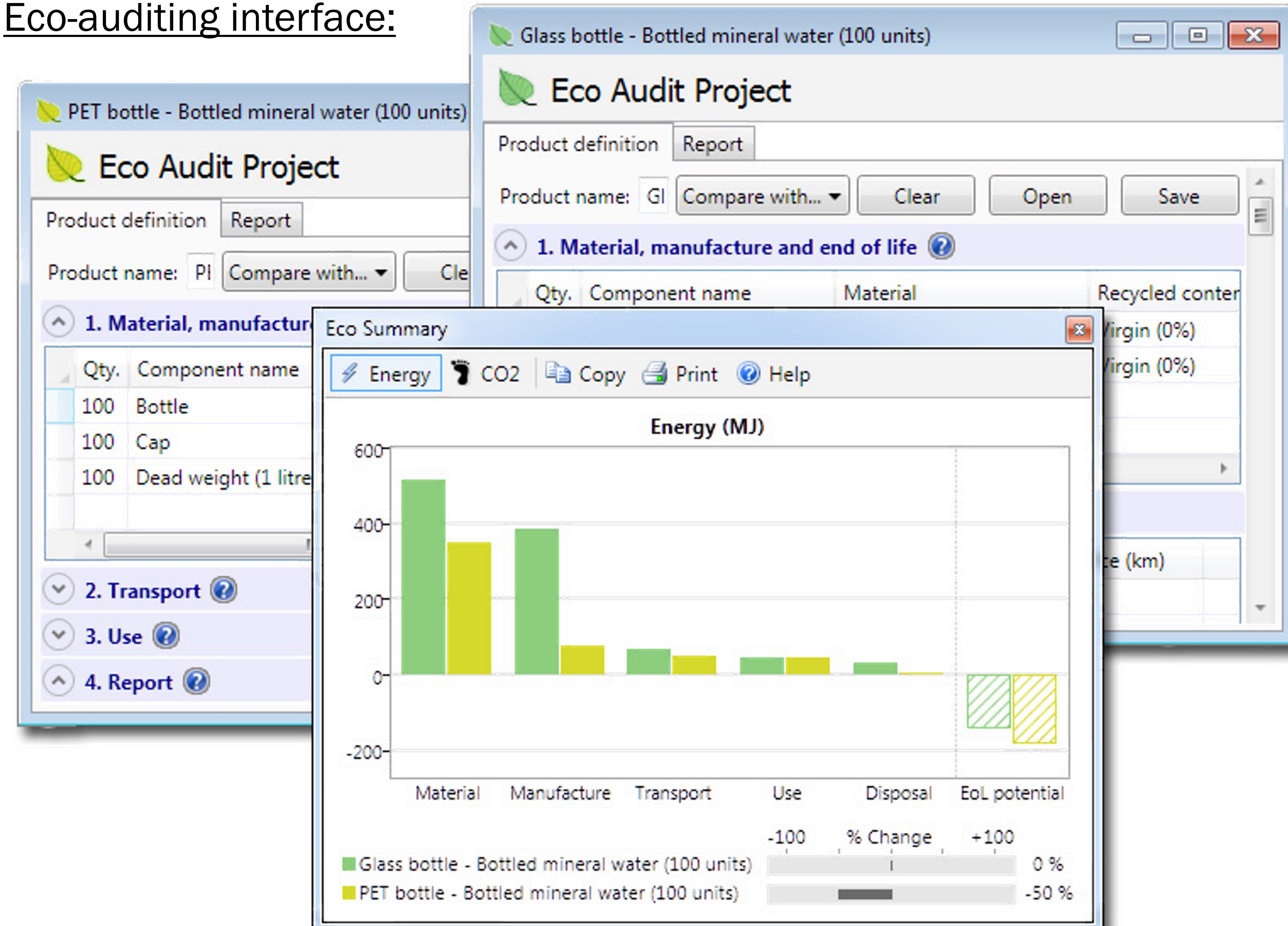
Impacts assessment:

- 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

Material selection interface:



Eco-auditing interface:



Using Edupack: Exercises

Edupack database: Three levels of detail

The CES EduPack software has three Levels of Database.

	Coverage	Content
Level 1	Around 70 of the most widely used materials drawn from the classes: metals, polymers, ceramics, composites, foams and natural materials. Around 70 of the most widely used processes.	A description, an image of the material in a familiar product, typical applications, and limited data for mechanical, thermal and electrical properties, using rankings where appropriate.
Level 2	Around 100 of the most widely used materials. Around 110 of the most commonly used processes.	All the content of Level 1, supplemented by more extensive numerical data, design guidelines, ecological properties and technical notes.
Level 3	The core database contains more than 3,750 materials, including those in Levels 1 and 2. Specialist editions covering aerospace, polymers, eco-design, architecture, bio-materials and low carbon power are also available.	Extensive numerical data for all materials, allowing the full power of the CES selection system to be deployed.

Source: Ashby (2013) CES Edupack tutorial

Each of the three levels can be interrogated by:

- **BROWSING**

Exploring the database and retrieving records via a hierarchical index.

- **SEARCHING**

Finding information via a full-text search of records.

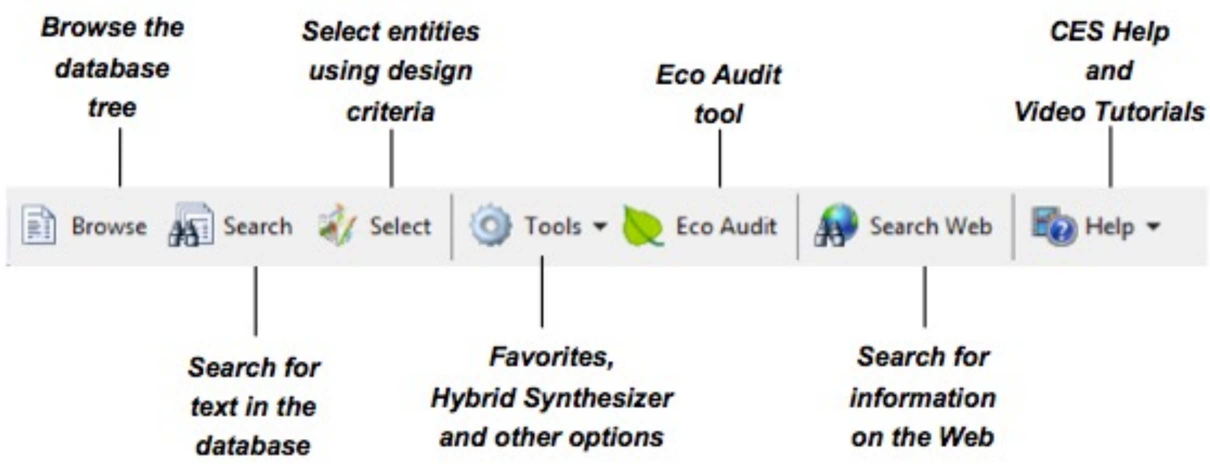
- **SELECTION**

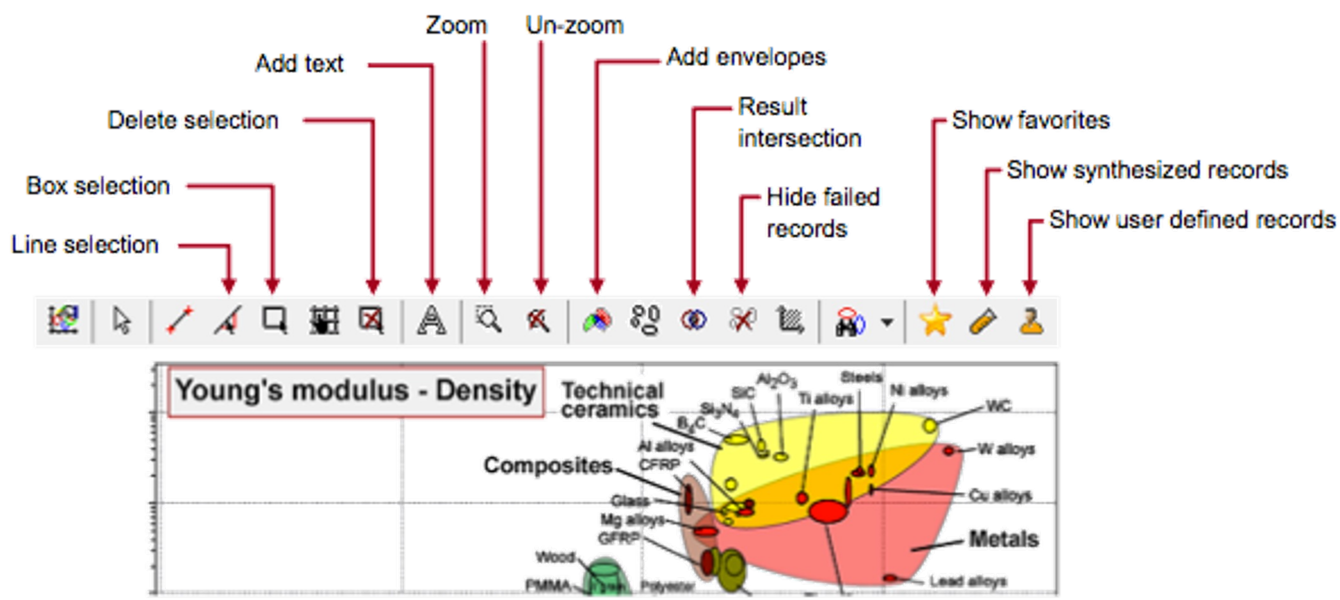
Using the powerful selection engine to find records that meet an array of design criteria.

And several interrogations can be combined into a single project…

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

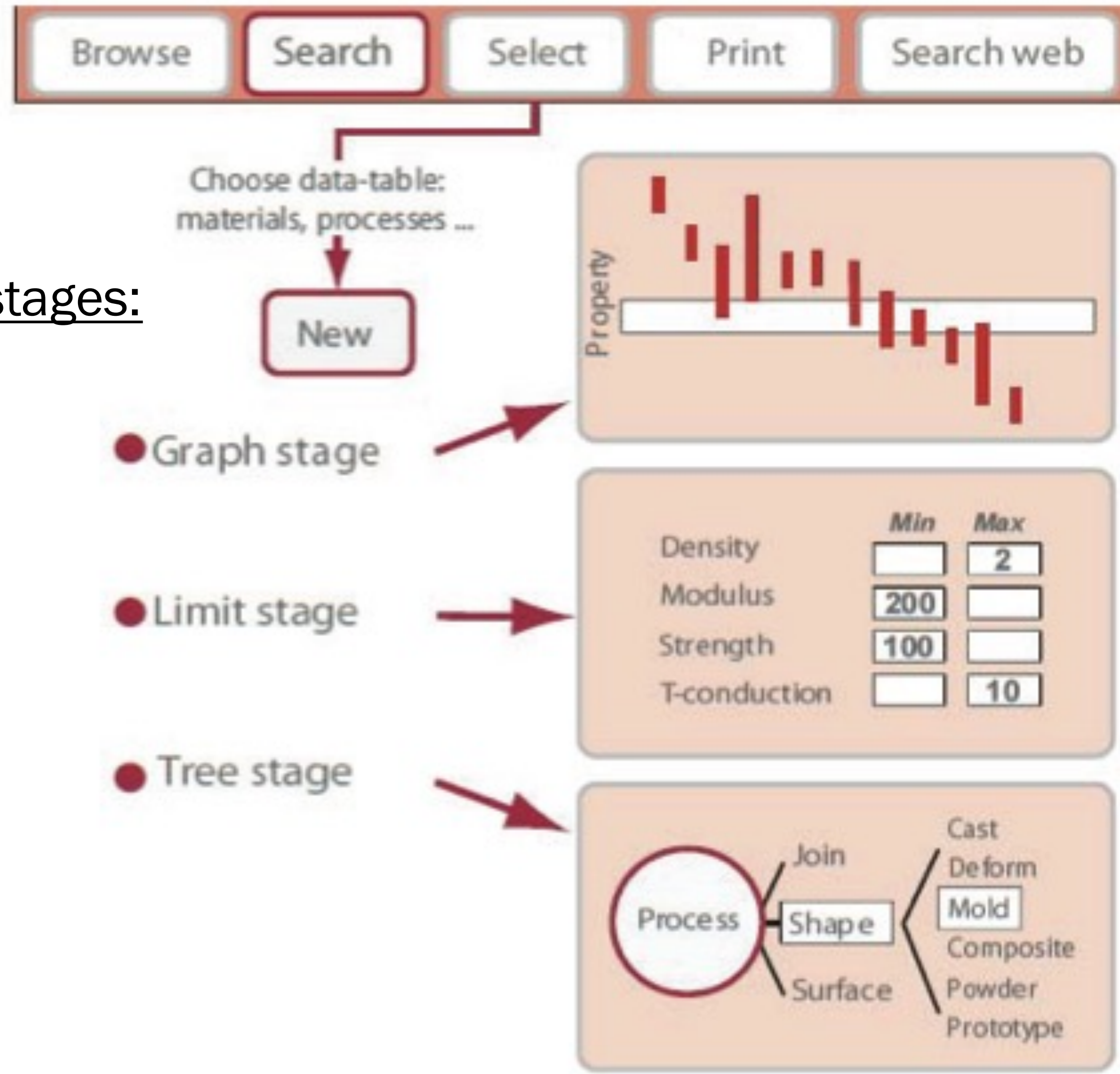
Standard and graph stage toolbars:





BROWSE, SEARCH and SELECT materials:

GRAPH, LIMIT and TREE stages:

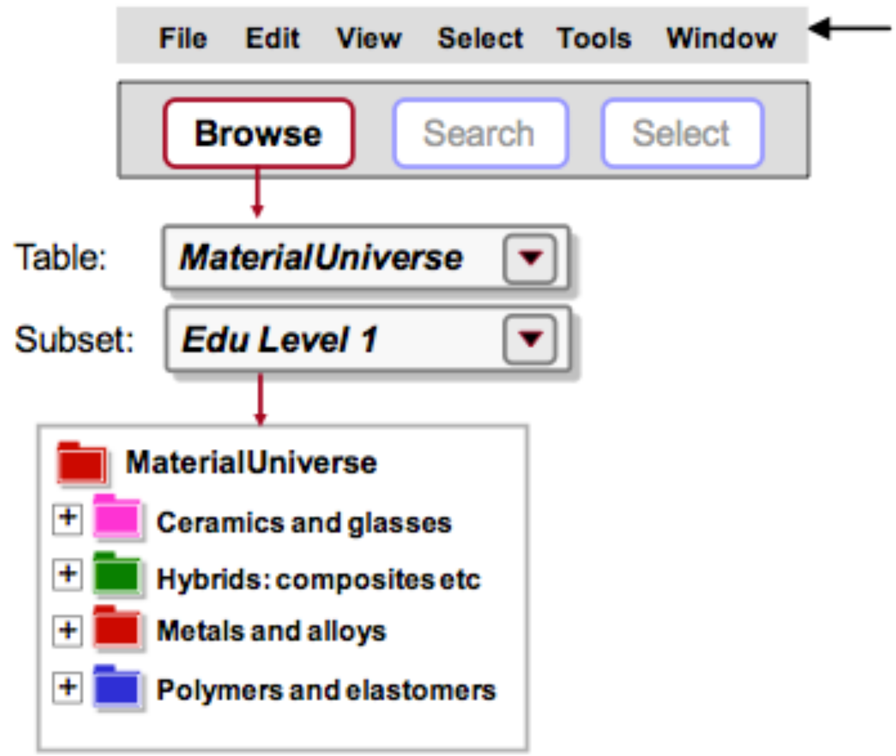


Exercises #1
BROWSING and SEARCHING

Using EduPack Levels 1 & 2

Exercise 1:
BROWSE Materials

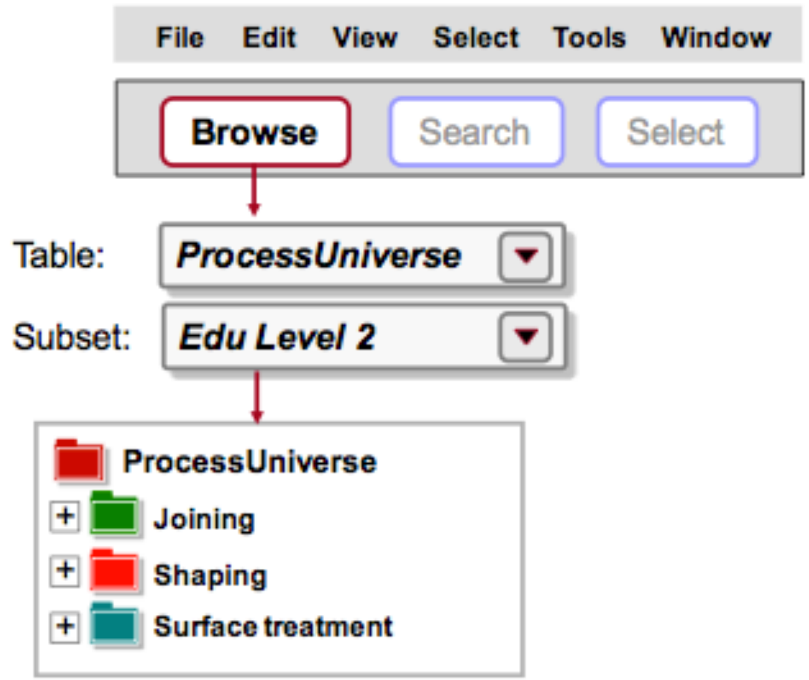
- Find record for STAINLESS STEEL (LEVEL 1)
- Find record for CONCRETE
- Find record for POLYPROPYLENE
- Find PROCESSES that can shape POLYPROPYLENE using the LINK at the bottom of the record
- Explore POLYPROPYLENE record at LEVEL 2
    - What else can be found?



Exercise 2:
BROWSE processes

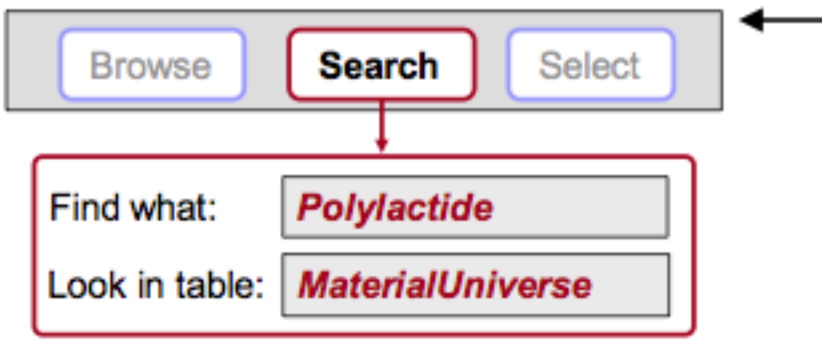
Select LEVEL 2, ALL PROCESSES

- Find record for INJECTION MOLDING
- Find record for LASER SURFACE HARDENING
- Find record for FRICTION WELDING (METALS)
- Find MATERIALS that can be DIE CAST, using the LINK at the bottom of the record for DIE CASTING



Exercise 3:
Applying SEARCH

- Find the material POLYLACTIDE
- Find materials for CUTTING TOOLS
- Find the process RTM



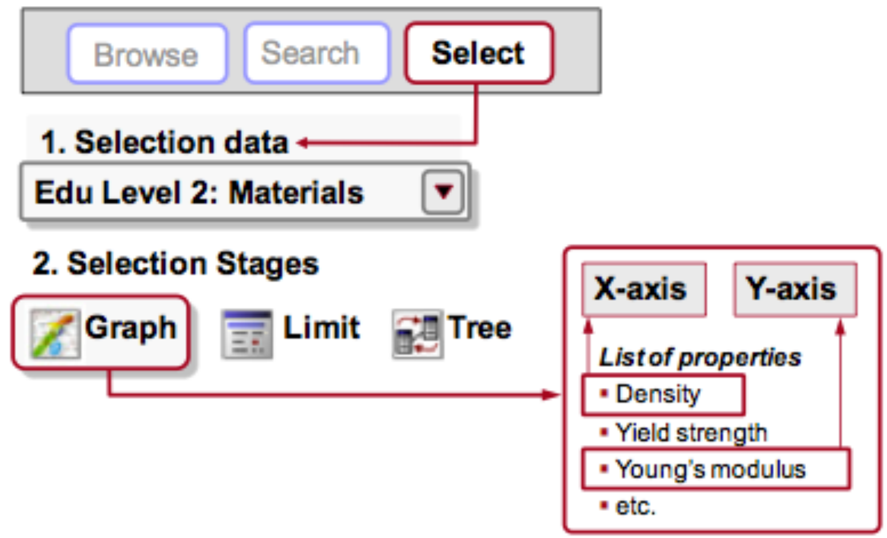
Familiarizing…

Exercises #2
PROPERTY CHARTS

Using EduPack Levels 1 & 2

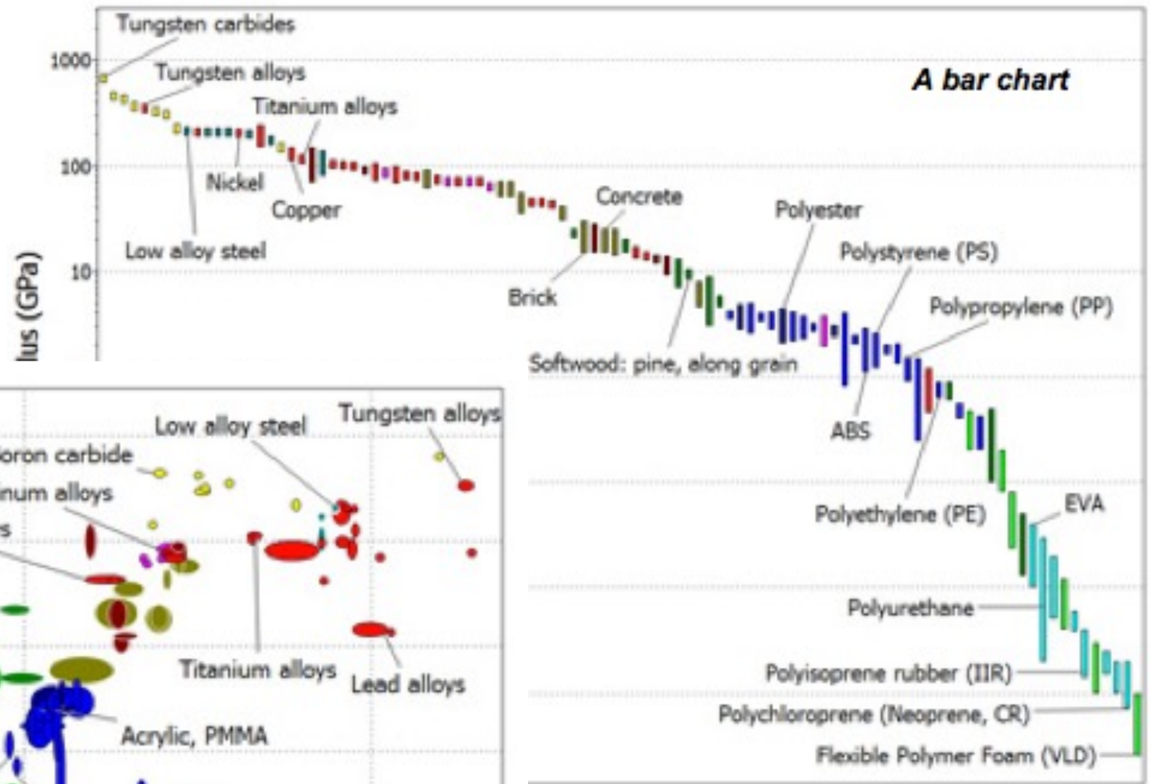
Exercise 4:
Making PROPERTY CHARTS

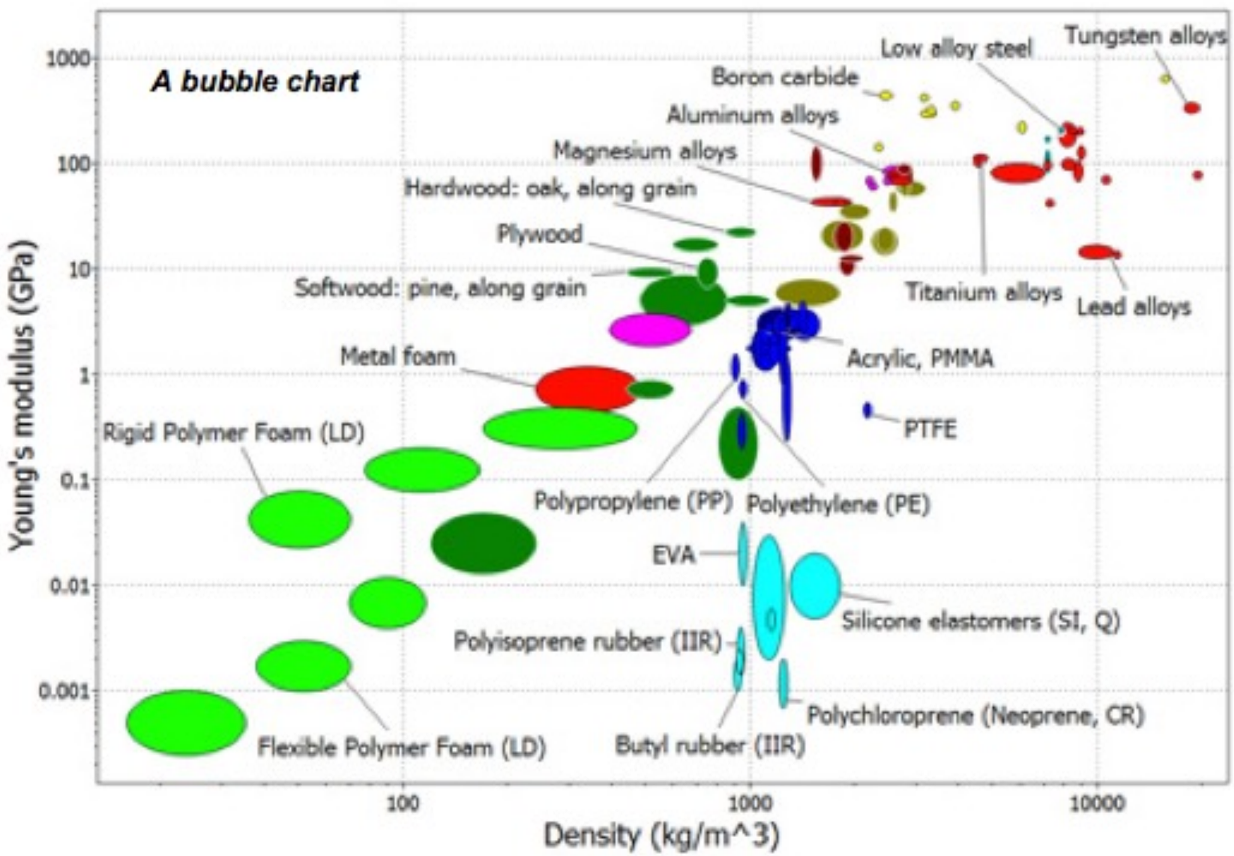
- SELECT MaterialUniverse: LEVEL 2, MATERIALS
- Make a BAR CHART of YOUNG'S MODULUS (E)
  - *Set only y-axis*
- Make a BUBBLE CHART of YOUNG'S MODULUS (E) VS. DENSITY (ρ)



  - *Set both x-axis and y-axis*
  - *Materials can be labeled – click and drag to move the labels; use DEL to delete a label*
- Finally, DELETE THE STAGE (Right click on stage in Selection Stages and select "Delete")

Charts with one – two axes & logarithmic scales:





Exercise 5:
Selection using a LIMIT stage

- Find materials with:

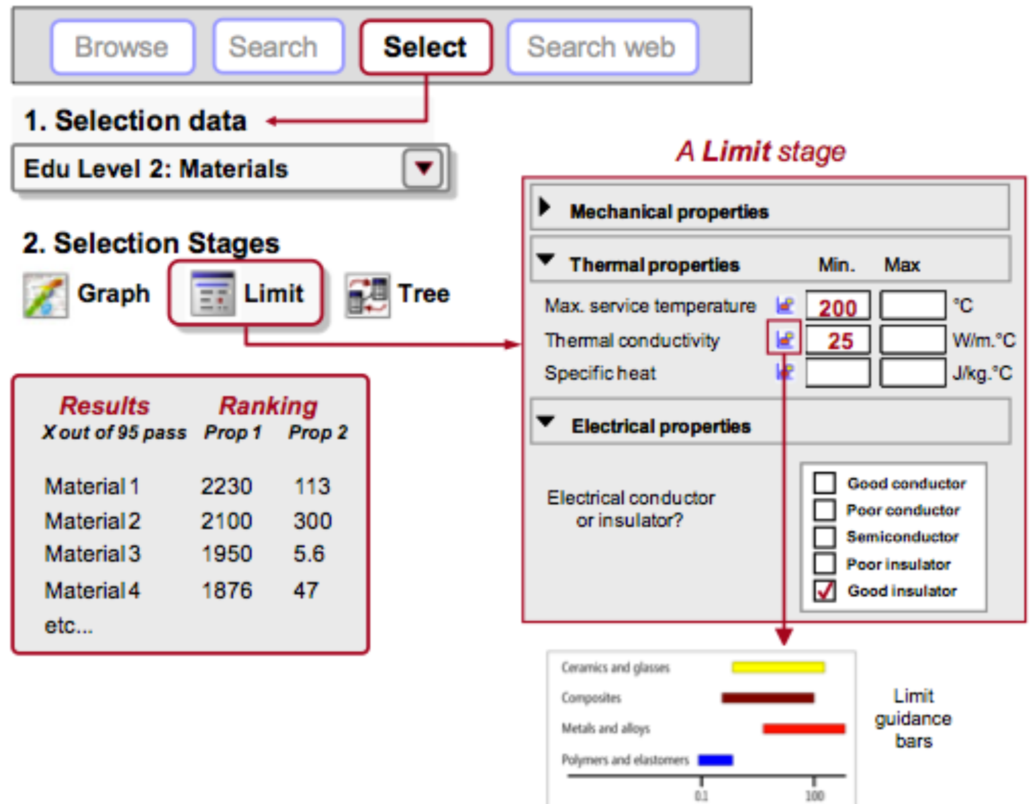
MAX. SERVICE TEMPERATURE
> 200 ° C

THERMAL CONDUCTIVITY
> 25 W/m.° C

ELECTRICAL CONDUCTOR OR INSULATOR?
= GOOD INSULATOR

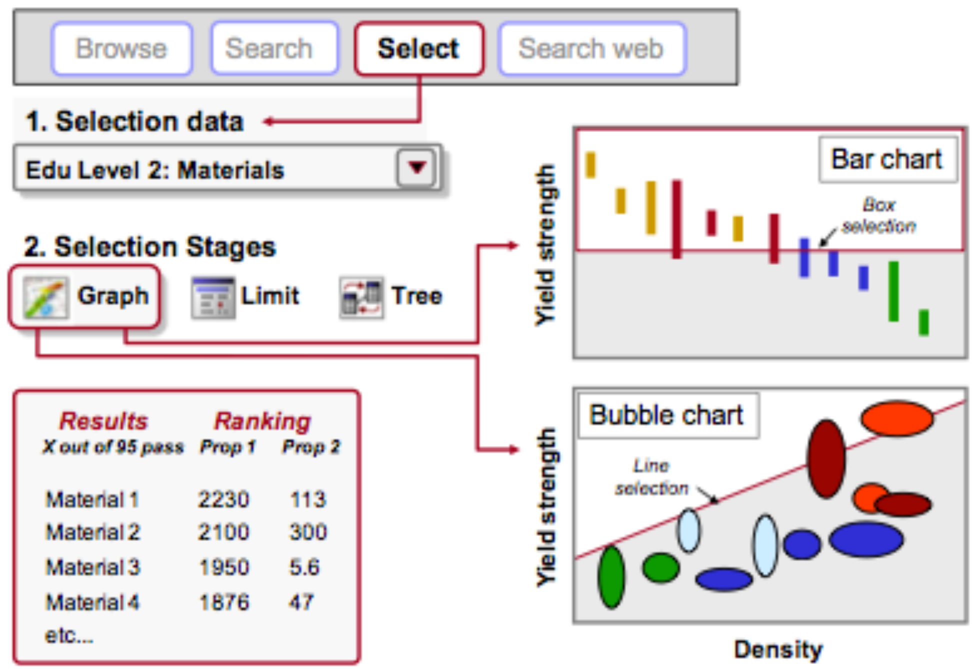
  – *Enter the limits – minimum or maximum as appropriate – and click "Apply"*

- DELETE THE STAGE



Exercise 6:
Selection with a GRAPH stage; 1/2

- Make a BAR CHART of YIELD STRENGTH (σy) (plotted on the y-axis)
- Use a BOX SELECTION to find materials with high values of elastic limit (or strength)
  - *Click the box icon, then click-drag-release to define it*
- Add, on the other axis, DENSITY (ρ):
  - *Either highlight Stage 1 in Selection Stages, right-click and choose Edit Stage from the menu; or double-click the graph axis to edit*

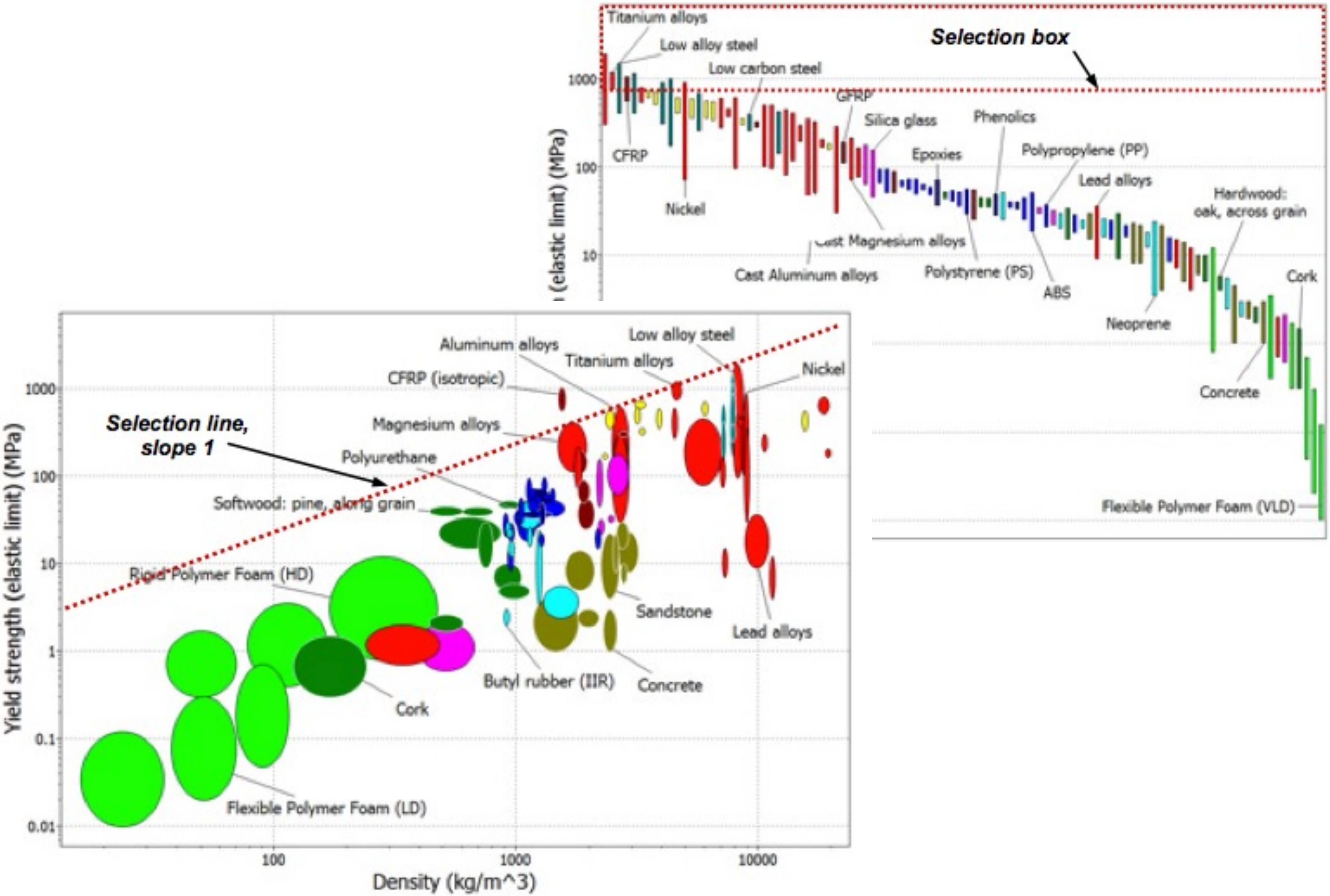


Exercise 6:
Selection with a GRAPH stage; 2/2

- Use a BOX SELECTION to find materials with high strength and low density

- Replace the BOX with a LINE SELECTION to find materials with high values of the "specific strength" (σ_y / ρ):
  - *Click the gradient line icon, then enter slope: "1" in this case.*
  - *Click on the graph to position the line through a particular point.*
  - *Click above or below the line to select an area: above the line for high values of σ_y / ρ in this case.*
  - *Now click on the line and drag upwards, to refine the selection to fewer materials*

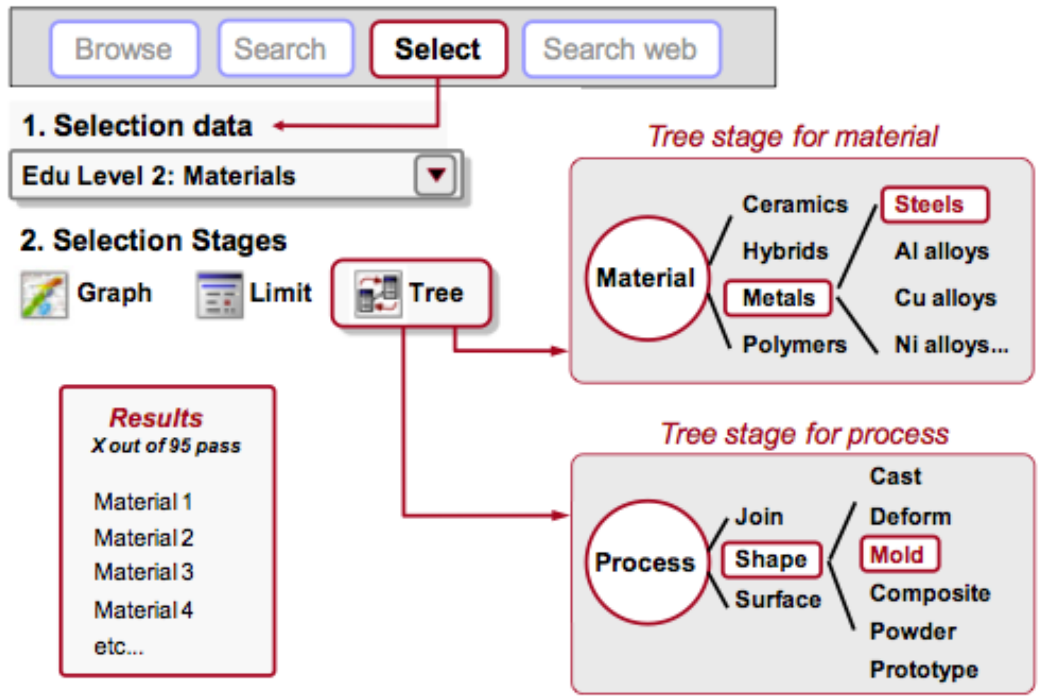
- DELETE THE STAGE



Titanium alloys
Low alloy steel
Selection box
Low carbon steel
1000
GFRP
Silica glass
Phenolics
CFRP
Polypropylene (PP)
100
Epoxies
Nickel
Lead alloys
Hardwood: oak, across grain
10
Cast Magnesium alloys
Cast Aluminum alloys
Polystyrene (PS)
ABS
Cork
Neoprene
Concrete
Flexible Polymer Foam (VLD)
Low alloy steel
Aluminum alloys
Titanium alloys
CFRP (isotropic)
Nickel
Selection line, slope 1
Magnesium alloys
Polyurethane
Softwood: pine, along grain
Rigid Polymer Foam (HD)
Sandstone
Lead alloys
Butyl rubber (IIR)
Concrete
Cork
Flexible Polymer Foam (LD)
Yield strength (elastic limit) (MPa)
1000
100
10
1
0.1
0.01
100
1000
10000
Density (kg/m^3)

Exercise 7:
Selection with a TREE Stage; 1/2

- Find MATERIALS that can be MOLDED
  - *In Tree Stage window, select ProcessUniverse, expand "Shaping" in the tree, select Molding, and click "Insert", then OK*
- DELETE THE STAGE



Exercise 7:
Selection with a TREE Stage; 2/2

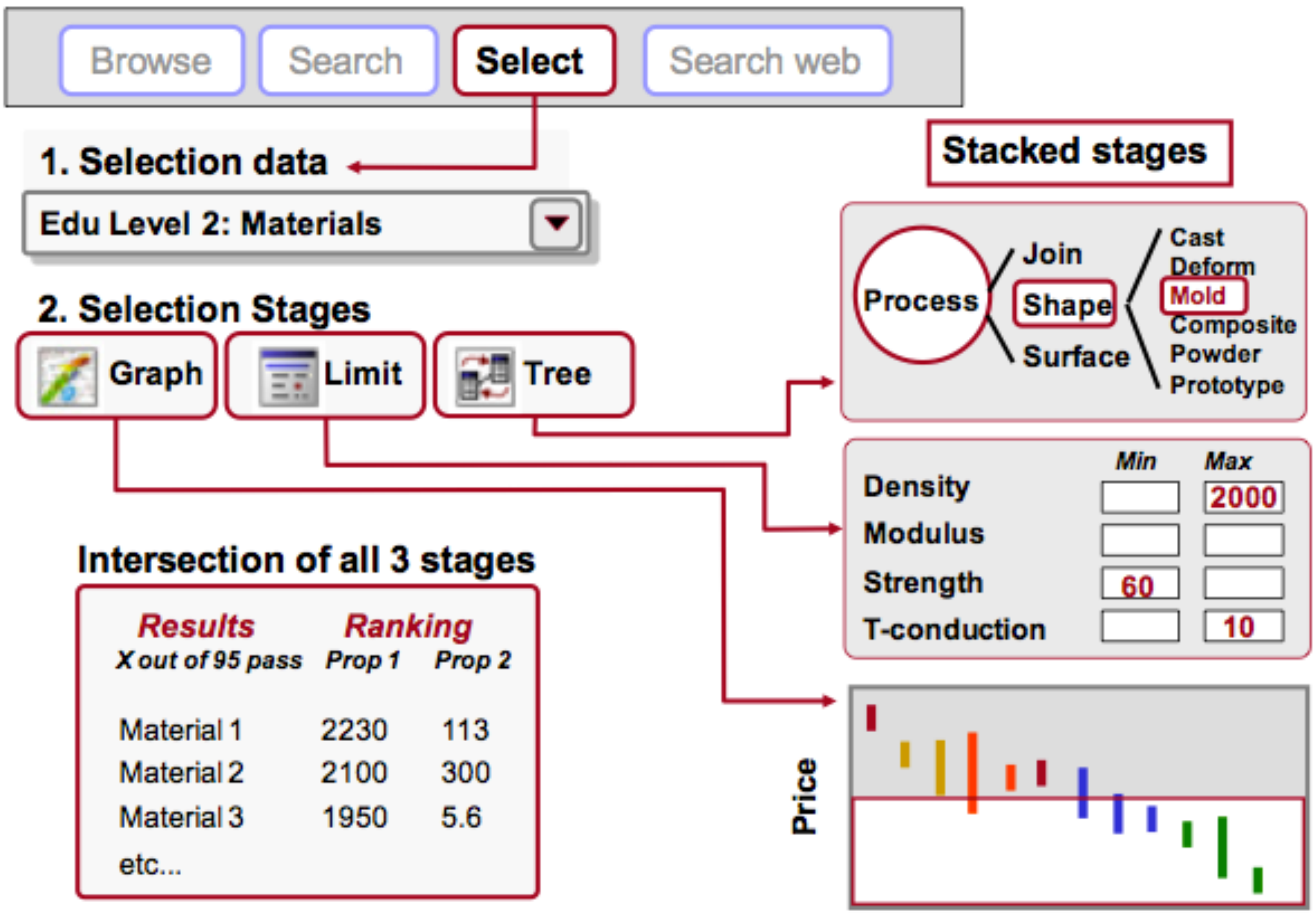
- Find PROCESSES to join STEELS
  - *First change Selection Data to select Processes: LEVEL 2, JOINING PROCESSES*
  - *Then, in Tree Stage window, select MaterialUniverse, expand "Metals and alloys" in the tree, select Ferrous, and click "Insert", then OK*

- DELETE THE STAGE

Exercises #3
GETTING ALL TOGETHER

Using EduPack Levels 1 & 2

Exercise 8:
Using ALL 3 STAGES together; 1/2



Exercise 8:
Using ALL 3 STAGES together; 2/2

- Find MATERIALS with the following properties:

DENSITY < 2000 kg/m3

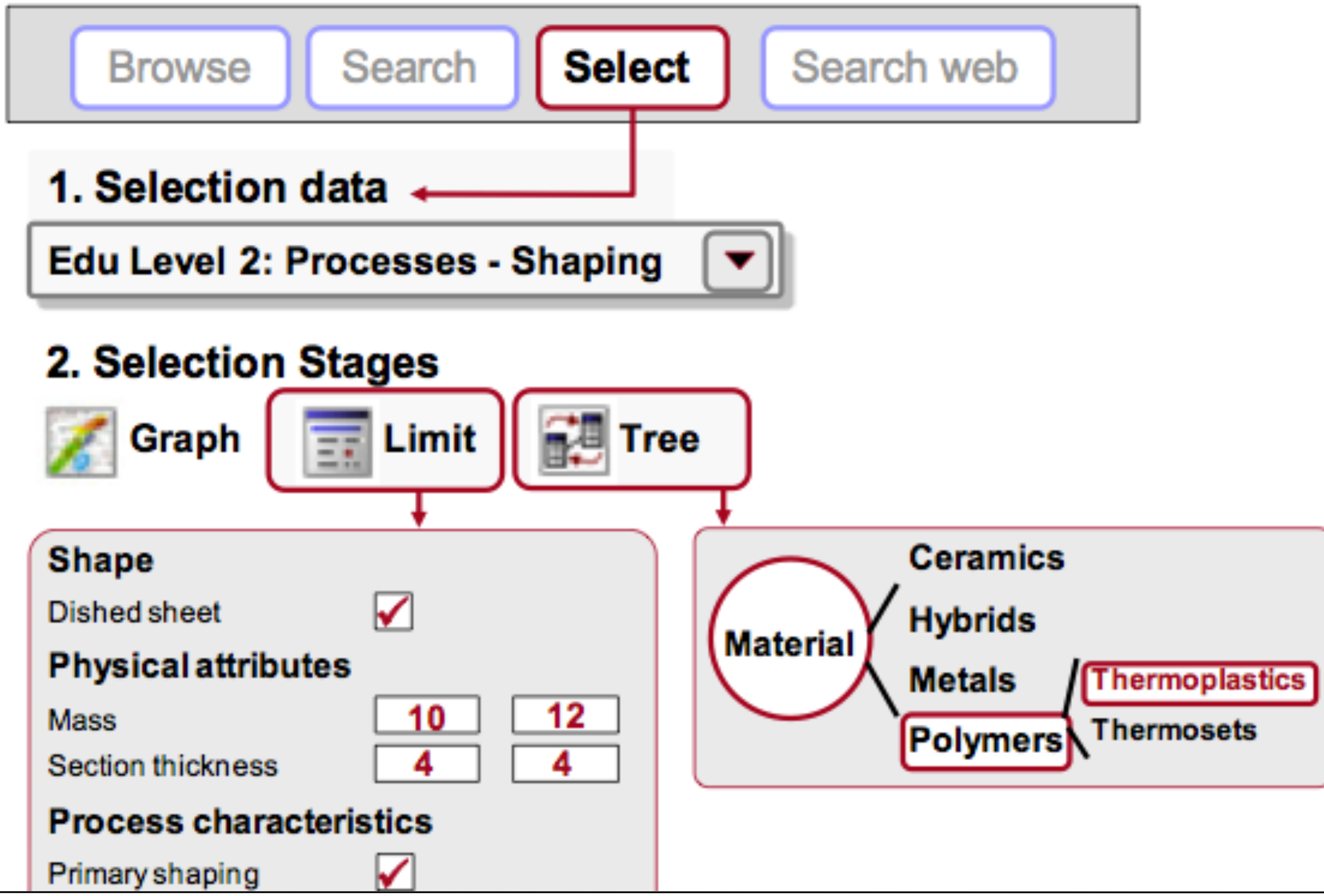
STRENGTH (Elastic limit) > 60 Mpa

THERMAL CONDUCTIVITY < 10 W/m.° C

  - *Change Selection Data to select Materials: Select LEVEL 2, MATERIALS*
  - *3 entries in a Limit Stage*

- Can be MOLDED (a Tree Stage: ProcessUniverse – Shaping – Molding)
- Rank the results by PRICE (a Graph Stage: bar chart of Price)
  - *On the final Graph Stage, all materials that fail one or more stages are grayed-out; label the remaining materials, which pass all stages*
  - *The RESULTS window shows the materials that pass all the stages*

Exercise 9:
Selecting PROCESSES; 1/2



Exercise 9:
Selecting PROCESSES; 2/2

- Find PRIMARY SHAPING PROCESSES to make a component with:

SHAPE = Dished sheet

MASS = 10–12kg

SECTION THICKNESS = 4 mm

PROCESS CHARASTERISTICS = Primary shaping process

ECONOMIC BATCH SIZE > 1000

  - *Change Selection Data to select Processes: Select LEVEL 2, SHAPING PROCESSES*
  - *5 entries in a Limit Stage*

- Made of a THERMOPLASTIC (a Tree Stage: MaterialUniverse – Polymers and elastomers – Polymers – Thermoplastics)

Presenting project ideas

Working with your project ideas…

- Introduce your initial project idea to others
- Upload idea as small text to MyCourses by next session…

In your project idea text, reflect on:

- Main objective, motivation, and assessment boundaries
- Focus life phases, parts of product(-service) system, and stakeholders
- Focus materials/impacts and potential alternatives for improvement

Working with your project ideas: Next steps

Continue reflection in greater detail:

1. Describe the prime objective in your project idea, eg. product assessment/comparison/redesign (step 1)
2. Define system boundaries for the assessment (step 1)
3. Review stakeholders and both production system and product components (step 2)
4. Perform fact-finding on stakeholders and components (Materials & Manufacturing; Environment; Society; Economics; Regulation; Design) (step 3)

Begin to perform assessment in Edupack:

5. Perform impact assessment/comparison with Edupack and Eco-audit tool
6. Reflect on results, communicate in report

Step 1:
Identifying objective and boundaries

- Identify the main objective of your design action, and how it may contribute to sustainability
- Identify the initial boundaries of your action and assessment
- *Where is your focus?*
- Begin to gather ’bill of materials’ (ie. list of main components and materials in comparison)
- Begin to consider material & socio-cultural (design) implications on a general level:
  - Use fact-finding sheet to assess contextual system and its sustainability
  - Use a matrix type of approach to consider focus materials, processes, and their impacts (eg. META matrix)

Example – META matrix:

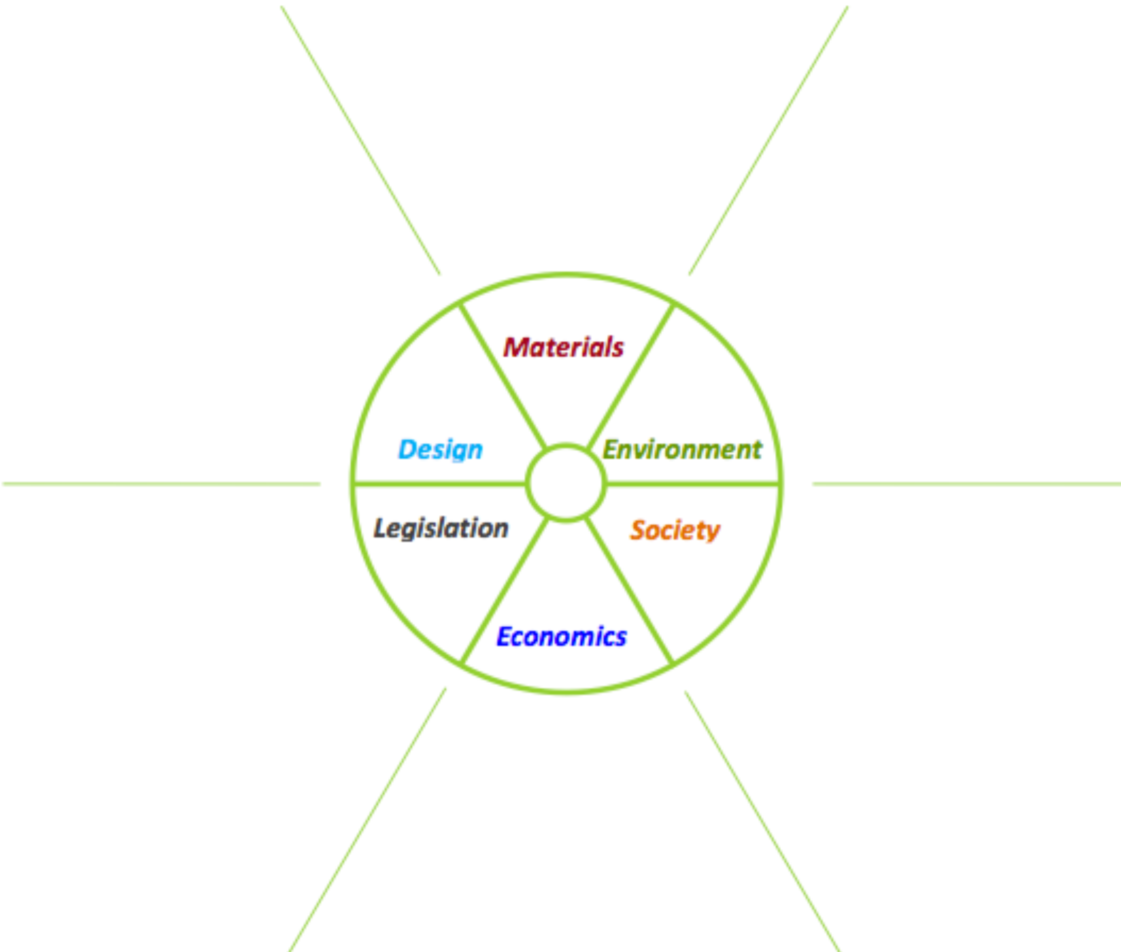
Impact category	Material production	Manufac-turing	Use-phase	End-life	Transport
M-Materials					
E-Energy					
T-Toxicity					
A-Socio-cultural					

Steps 2-3:
System and stakeholder analysis

- Begin to analyze the overall life phases and involved stakeholders of the system
- Consider focus materials and related stakeholders
- What to tackle with your contribution? Iteration of the objectives…
- *Where to focus with improvements?*
- *Who to involve?*

1. Prime Objective and Scale:

3. Fact - finding



2. Stakeholders

THANKS!
Continues on Thursday 19.1.

(See readings online…)