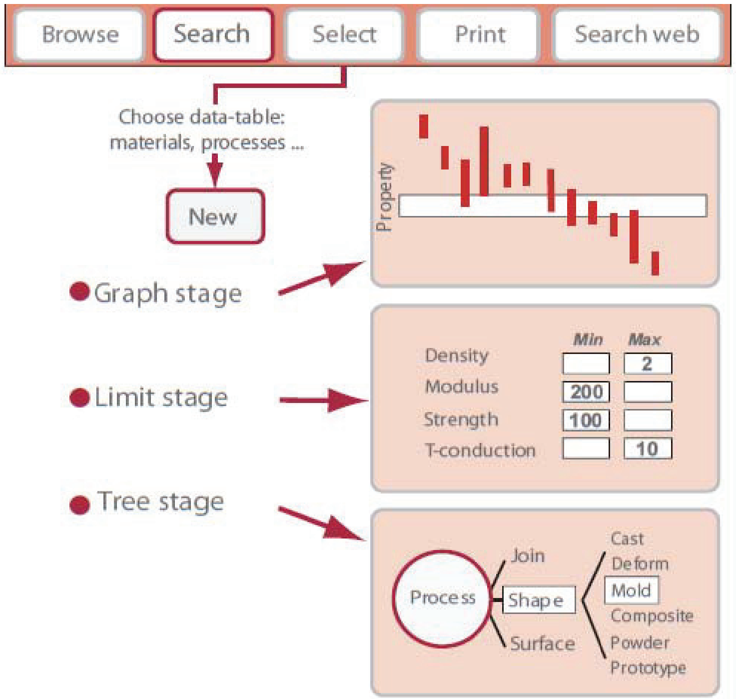

GRANTA CES 2012 EDUPACK

Getting Started Guide

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GRANTA TEACHING RESOURCES

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This Getting Started Guide is part of a set of open access teaching resources 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. Some like this are open access.

www.grantadesign.com/education/resources

Getting started with CES EduPack

These exercises give an easy way to learn to use the CES EduPack software.
The comprehensive CES Help file within the software gives more detailed guidance.

Thumbnail sketch of CES EduPack

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.

When the software opens you are asked to choose a Level. Chose Level 1 to start with.

At each Level there are a number of Data Tables.

The most important are: Materials and Processes.

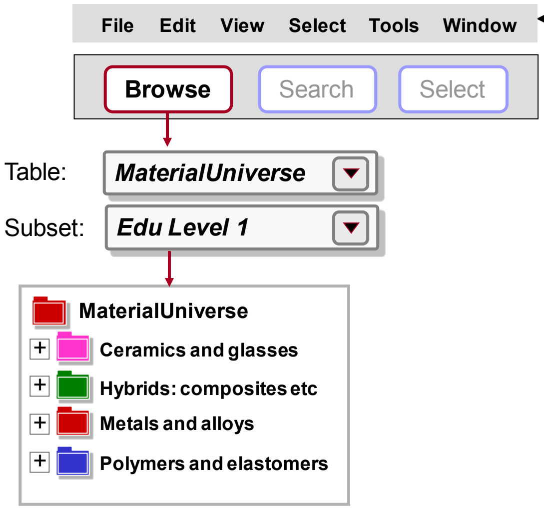
Each of the three levels can be interrogated by

- **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.

CES EduPack does far more than this. But this is enough to get started.

BROWSING and SEARCHING

The DEFAULT on loading CES EduPack Levels 1 & 2 is LEVEL 1, MATERIALUNIVERSE



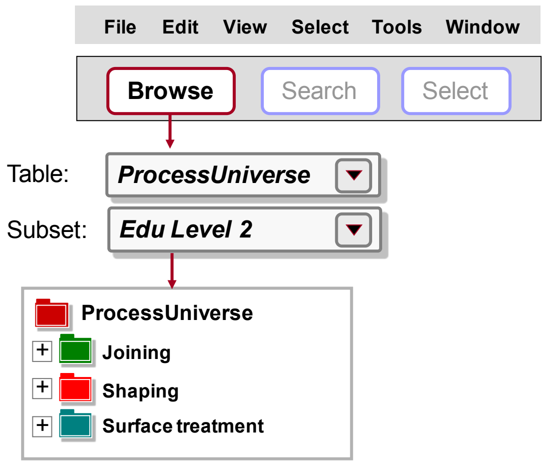
Exercise 1 BROWSE materials

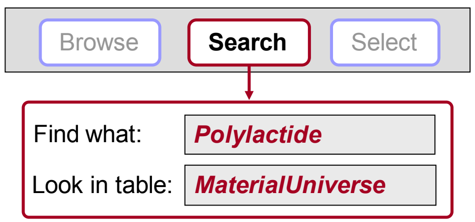
- Find record for STAINLESS STEEL
- Find record for CONCRETE
- Find record for POLYPROPYLENE
- Explore POLYPROPYLENE record at LEVEL 2
- Find PROCESSES that can shape POLYPROPYLENE using the LINK at the bottom of the record

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 The SEARCH facility

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

(Part of a material record and a process record are shown overleaf)

Part of a record for a material: polypropylene

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

PP

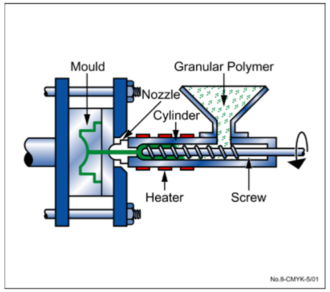
Design guidelines
Standard grade PP is inexpensive, light and ductile but it has low strength. It is more rigid than PE and can be used at higher temperatures. The properties of PP are similar to those of HDPE but it is stiffer and melts at a higher temperature (165 - 170 C). Stiffness and strength can 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
Ropes, general polymer engineering, automobile air ducting, parcel shelving and air-cleaners, garden furniture, washing machine tank, wet-cell battery cases, pipes and pipe fittings, beer bottle crates, chair shells, capacitor dielectrics, cable insulation, kitchen kettles, car bumpers, shatter proof glasses, crates, suitcases, artificial turf, thermal underwear.

Part of a record for a process: injection molding

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

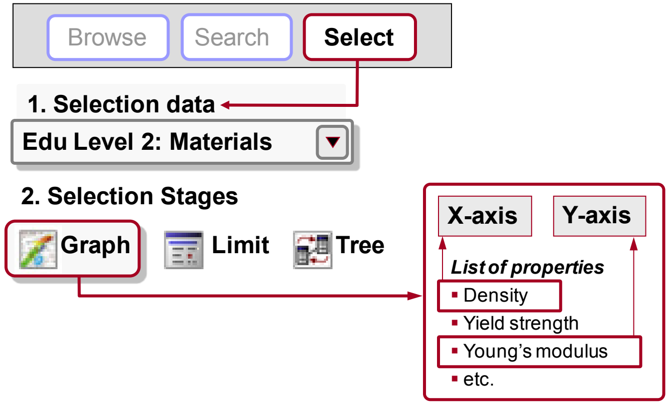
Design guidelines
Injection molding is the best way to mass-produce small, precise, polymer components with complex shapes. The surface finish is good; texture and pattern can be easily altered in the tool, and fine detail reproduces well. Decorative labels can be molded onto the surface of the component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

Technical notes
Most thermoplastics can be injection molded, although those with high melting temperatures (e.g. PTFE) are difficult. Thermoplastic-based composites (short fiber and particulate filled) can be processed providing the filler-loading is not too large. Large changes in section area are not recommended. Small re-entrant angles and complex shapes are possible, though some features (e.g. undercuts, screw threads, inserts) may result in increased tooling costs. The process may also be used with thermosets and elastomers. 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.

Typical uses
Extremely varied. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses, etc.

The economics
Capital cost are medium to high, tooling costs are usually high - making injection molding economic only for large batch sizes. Production rate can be high particularly for small moldings. Multi-cavity molds are often used. Prototype moldings can be made using single cavity molds of cheaper materials. Typical products. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses.

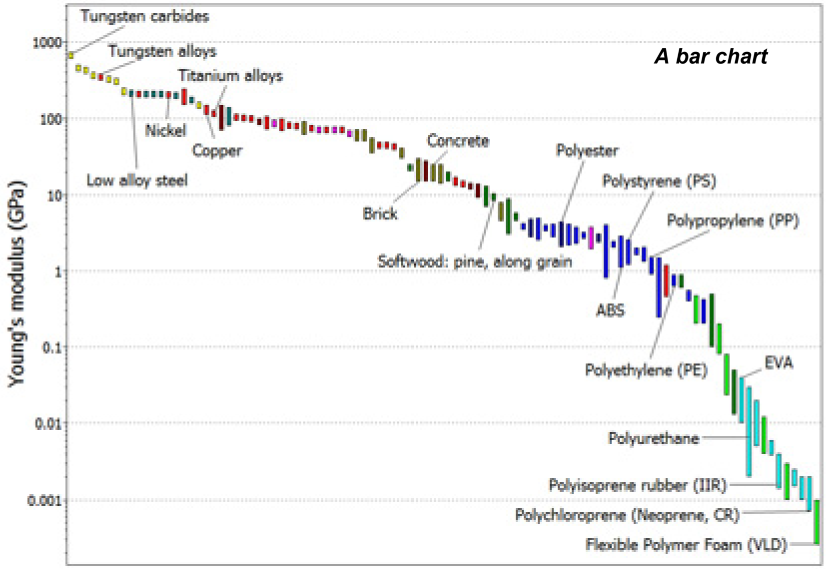
PROPERTY CHARTS

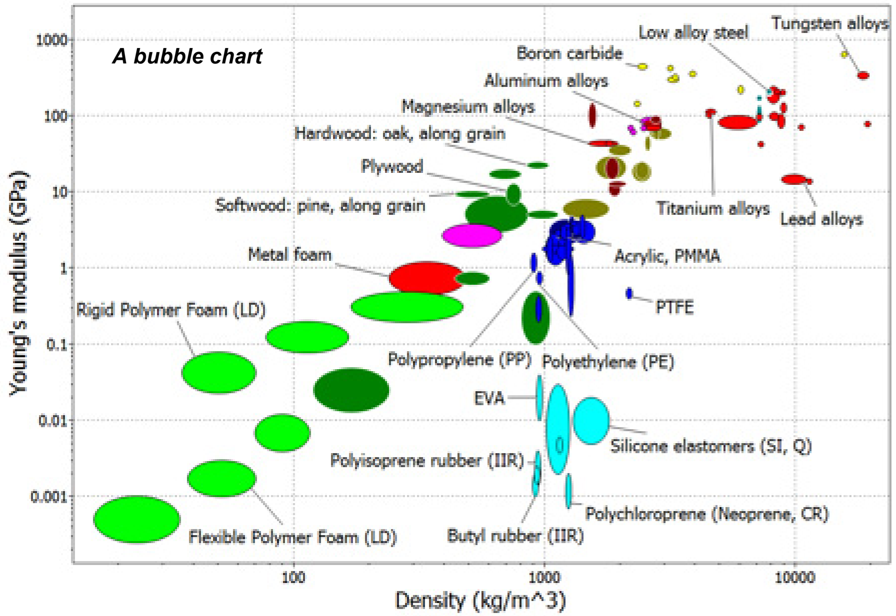


Exercise 4 Making PROPERTY CHARTS

- Select MaterialUniverse: LEVEL 2, MATERIALS
- Make a BAR CHART of YOUNG'S MODULUS (E)
  (Set y-axis to Young's modulus; leave x-axis at <None>)
  (Click on a few materials to label them; double-click to go to their record in the Data Table)
- Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY (ρ)
  (Set both x-axis and y-axis; the default is a log-log plot)
  (Materials can be labeled as before – click and drag to move the labels; use DEL to delete a label)

DELETE THE STAGE
(Right click on stage in Selection Stages and select "Delete")





SELECTION using a LIMIT STAGE

Exercise 5 Selection using a LIMIT stage

- Find materials with:

  MAX. SERVICE TEMPERATURE > 200 °C

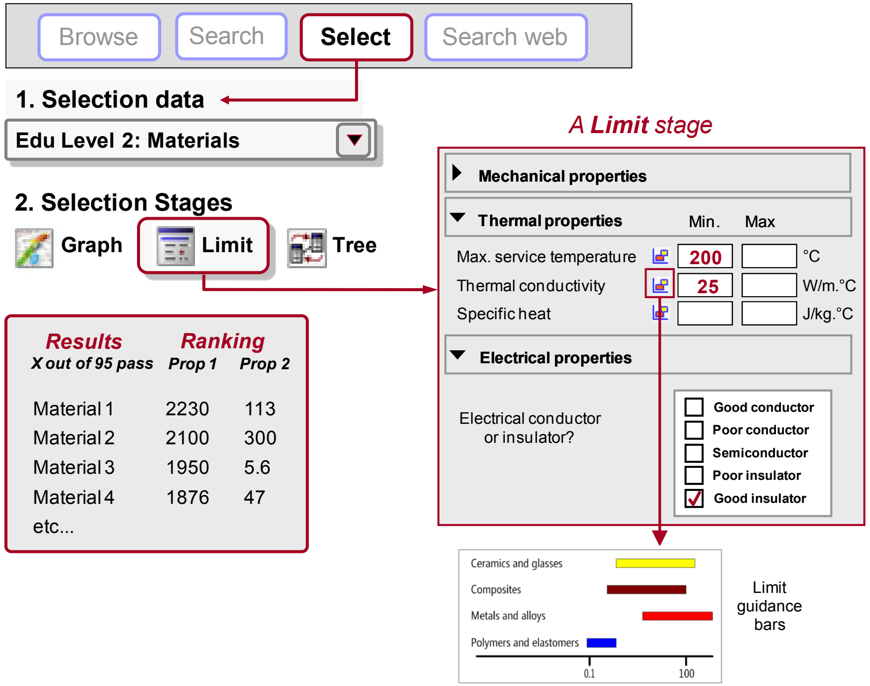
  THERMAL CONDUCTIVITY > 25 W/m.°C

  ELECTRICAL CONDUCTOR OR INSULATOR? = GOOD INSULATOR

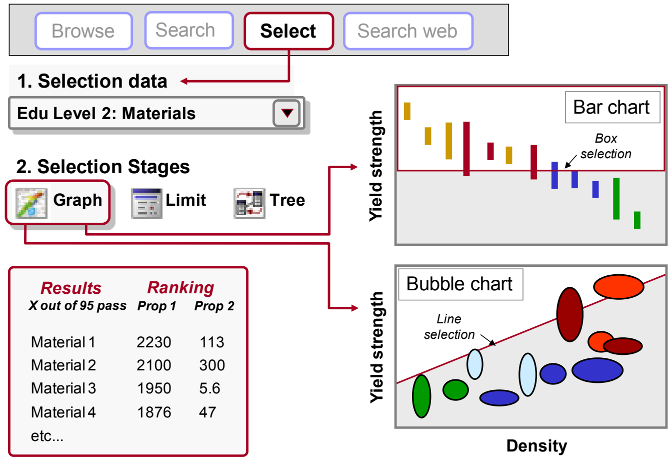
  (Enter the limits – minimum or maximum as appropriate – and click "Apply")

  (Results at Level 1 or 2: aluminum nitride, alumina, silicon nitride)

DELETE THE STAGE



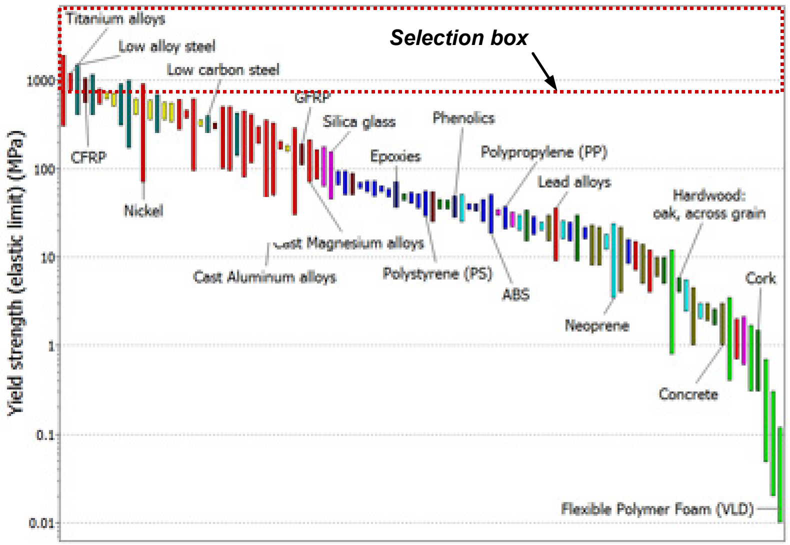
GRAPH SELECTION

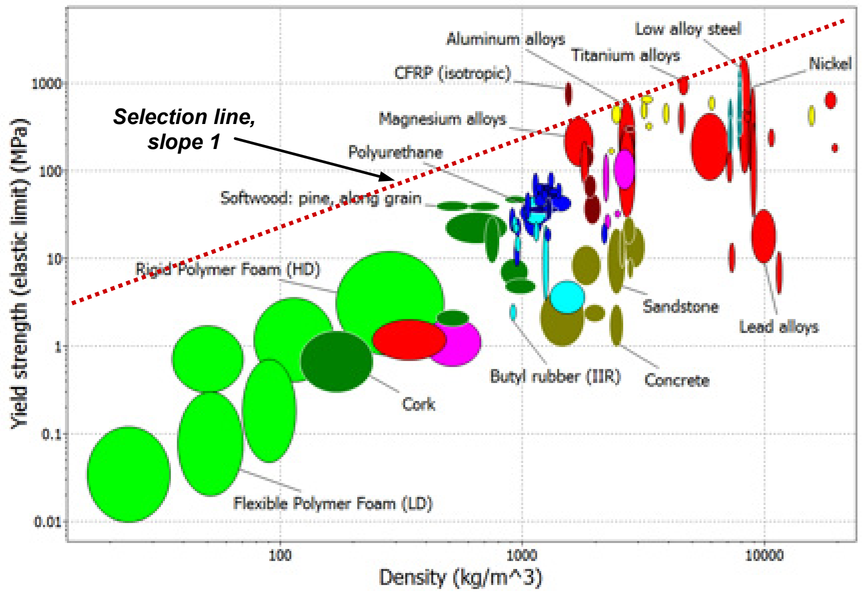


Exercise 6 Selection with a GRAPH stage

- Make a BAR CHART of YIELD STRENGTH (σ_y) (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 the box)
- 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)
- 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.)

(Results at Level 1 or 2: CFRP (isotropic), Titanium alloys, Magnesium alloys, …) DELETE THE STAGE





TREE SELECTION

Exercise 7 Selection with a TREE Stage

- Find MATERIALS that can be MOLDED

  (In Tree Stage window, select ProcessUniverse, expand "Shaping" in the tree, select Molding, and click "Insert", then OK)

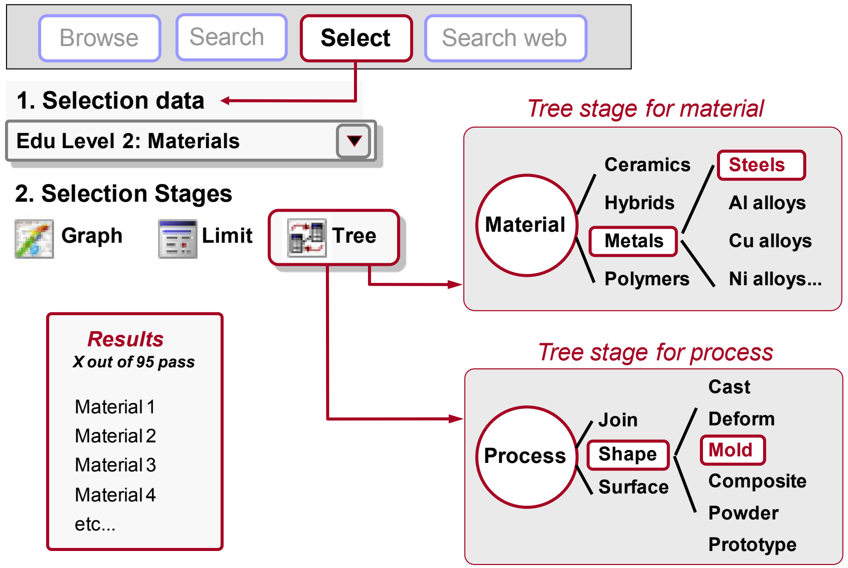
DELETE THE STAGE

- 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



GETTING IT ALL TOGETHER

Exercise 8 Using ALL 3 STAGES together

Change Selection Data to select Materials:
    Select LEVEL 2, MATERIALS

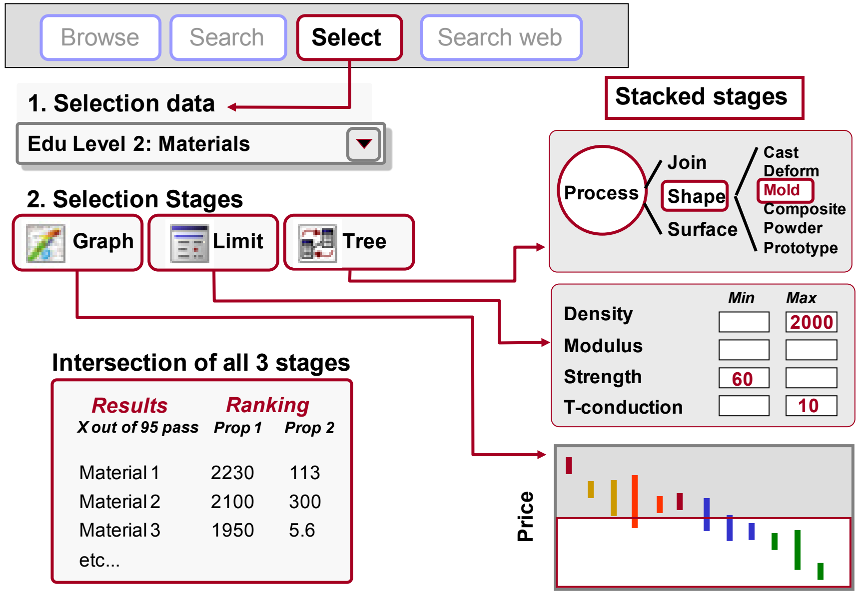
Find MATERIALS with the following properties

- DENSITY < 2000 kg/m^3
- STRENGTH (Elastic limit) > 60 MPa
- THERMAL CONDUCTIVITY < 10 W/m.°C
  (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.)

(Results, cheapest first: PET, POM, Polylactide, ...)



Exercise 9 Finding SUPPORTING INFORMATION

(Requires Internet connection)

- With the PET record open, click on SEARCH WEB
  (CES EduPack translates the material ID to strings compatible with a group of high-quality material and process information sources and delivers the hits. Some of the sources are open access, others require a subscriber-based password. The ASM source is particularly recommended.)

CLOSE THE DATASHEET

PROCESS SELECTION

Exercise 10 Selecting PROCESSES

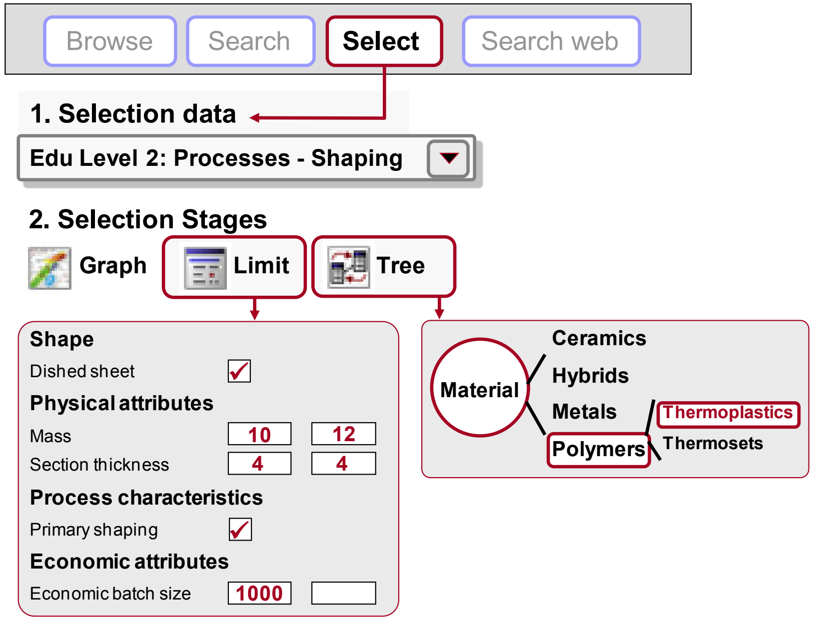
Change Selection Data to select Processes:
Select LEVEL 2, SHAPING PROCESSES

Find PRIMARY SHAPING PROCESSES to make a component with:

- SHAPE = Dished sheet
- MASS = 10 – 12 kg
- SECTION THICKNESS = 4 mm
- ECONOMIC BATCH SIZE > 1000
  (5 entries in a Limit Stage)

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

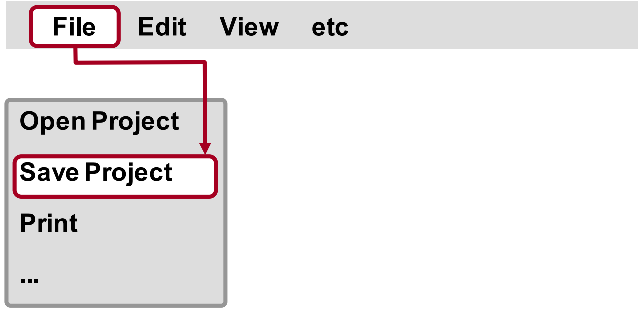
(Results: compression molding, rotational molding, thermoforming)



SAVING, COPYING and REPORT WRITING

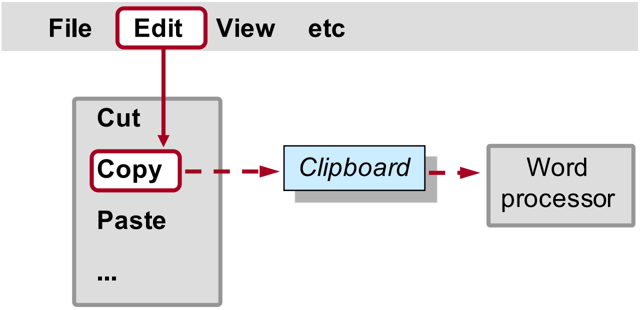
Exercise 11 Saving Selection Stages as a PROJECT

- SAVE the project – exactly as if saving a file in Word
  (give it a filename and directory location;
  CES EduPack project files have the extension ".ces")



Exercise 12 COPYING CES OUTPUT into a Document

Charts, Records and Results lists may be copied (CTRL-C) and pasted (CTRL-V) into a word processor application



- Display a chart, click on it, then COPY and PASTE it into a document
- Double click a selected material in the Results window to display its datasheet, click on the datasheet, then COPY and PASTE it
- Click on the Results window, then COPY and PASTE it
- Try editing the document

(The datasheets in Exercise 3 and the selection charts in Exercises 4 and 6 were made in this way)

(Warning: There is a problem with WORD 2000: the image in the record is not transferred with the text. The problem is overcome by copying the image and pasting it separately into the WORD document as a DEVICE INDEPENDENT BITMAP.)

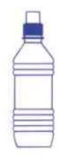
ECO AUDIT

The Eco Audit Tool calculates the energy used and CO_2 produced during five key life phases of a product (material, manufacture, transport, use and end of life) and identifies which is the dominant phase. This is the starting point for eco-aware product design, as it identifies which parameters need to be targeted to reduce the eco-footprint of the product.

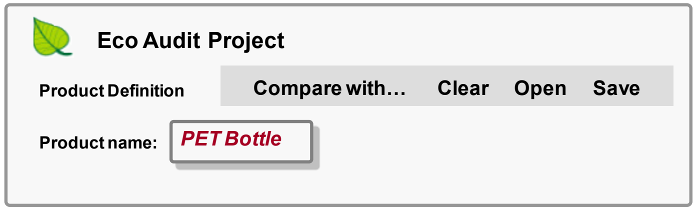
An example Eco Audit product file (.prd) for this case study is installed with CES EduPack in the 'Samples' folder.

Exercise 13 ECO AUDIT Project

A brand of bottled mineral water is sold in 1 liter PET bottles with polypropylene caps. A bottle weighs 40 grams; the cap 1 gram. Bottles and caps are molded, filled, and transported 550 km from the French Alps to England by 14 tonne truck, refrigerated for 2 days and then sold. The overall life of the bottle is one year.



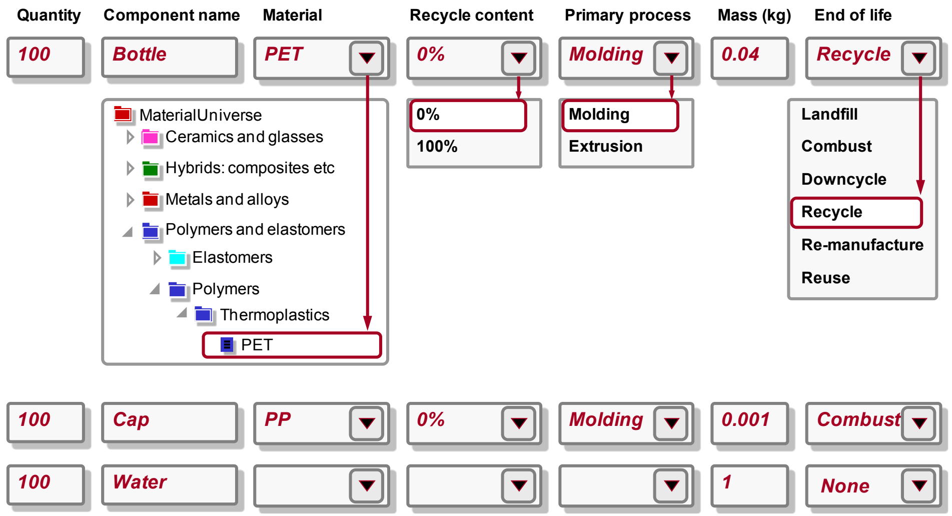
Product Definition



(For an explanation of the calculations used in each stage, click the help icon in the heading)

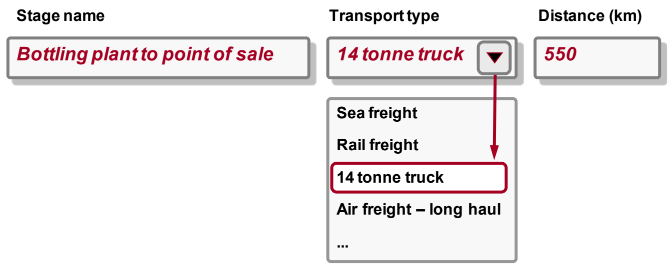
1. Material, manufacture and end of life

Bill of materials, primary processing techniques and end of life



2. Transport

Transportation from site of manufacture to point of sale

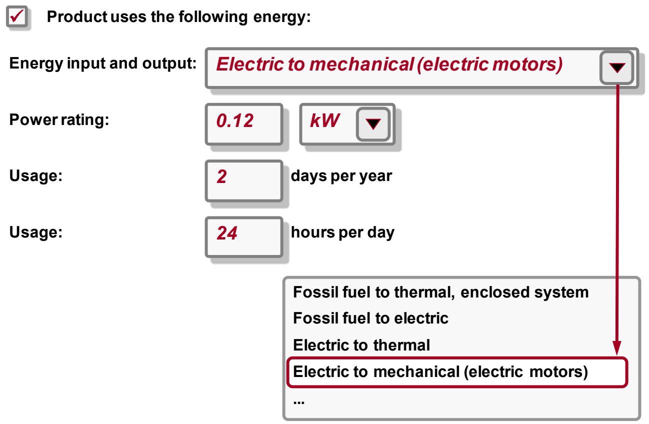


3. Use

Product life and location of use

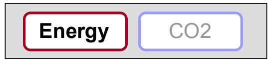
Static mode

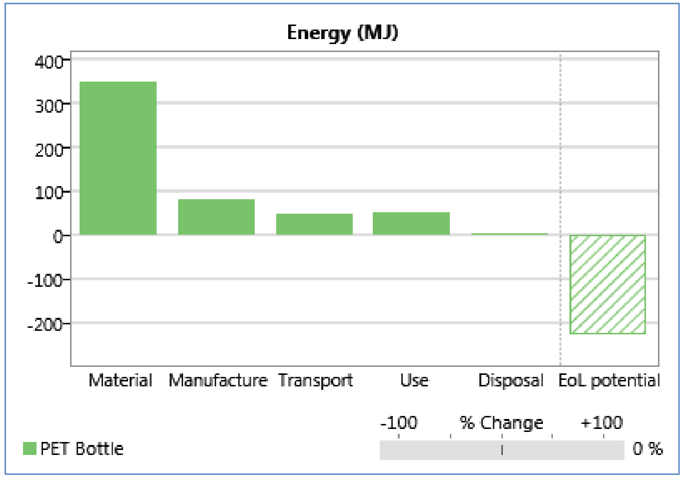
Energy used to refrigerate product at point of sale (average energy required to refrigerate 100 bottles at 4°C = 0.12 kW)



4. Report

enables rapid identification of the dominant life phase. View energy usage or CO_2 footprint.





(Result: Material is the dominant life phase)

- Click on the Material life phase bar in the summary chart for guidance on strategies to reduce its impact

provides a component by component breakdown of each life phase, enabling the main contributors to the dominant phase to be identified

Exercise 14 COMPARE Eco Audits

- Compare eco audits

(In Product Definition page, click "Compare with", then select Copy of current product.)

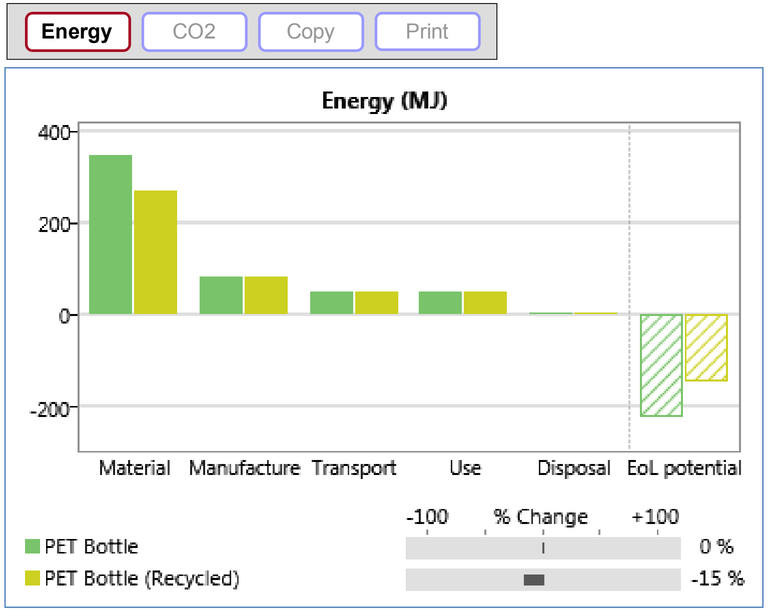
- In the copy, change product name to 'PET Bottle (Recycled)'

For the material PET

- Change the RECYCLED CONTENT to 35%

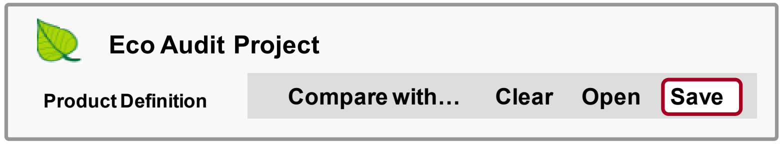
Note the first life energy (not including the 'EoL potential') is reduced by 15%

- Click COPY to copy the chart and PASTE it into a document



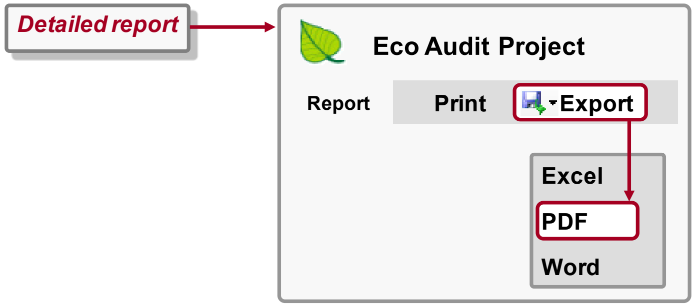
Exercise 15 Saving Eco Audit Product Definition

Eco audit projects do not form part of a selection project and need to be saved separately



- SAVE the product definition (give it a filename and directory location; Eco Audit product files have the extension ".prd")

Exercise 16 Saving/Exporting Eco Audit Report



- GENERATE the eco audit report
- EXPORT the eco audit report as a PDF

(Note: You will require Microsoft Excel or a PDF reader such as Adobe Reader to view the exported eco audit report)

Toolbars in CES EduPack

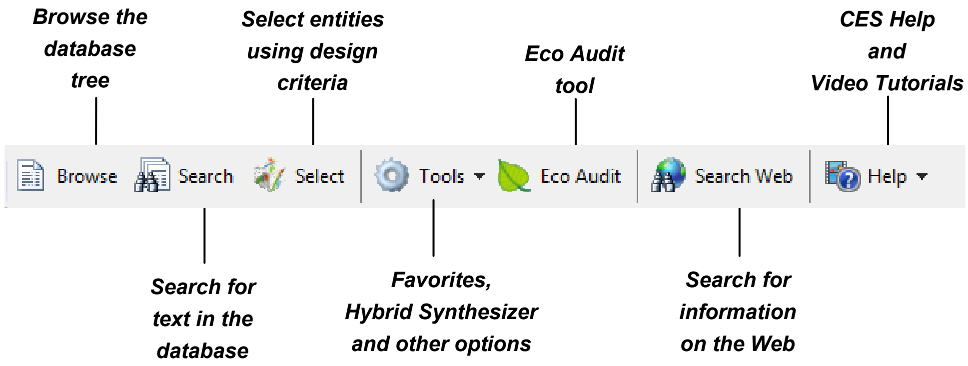


Figure A1. The Standard toolbar in CES EduPack

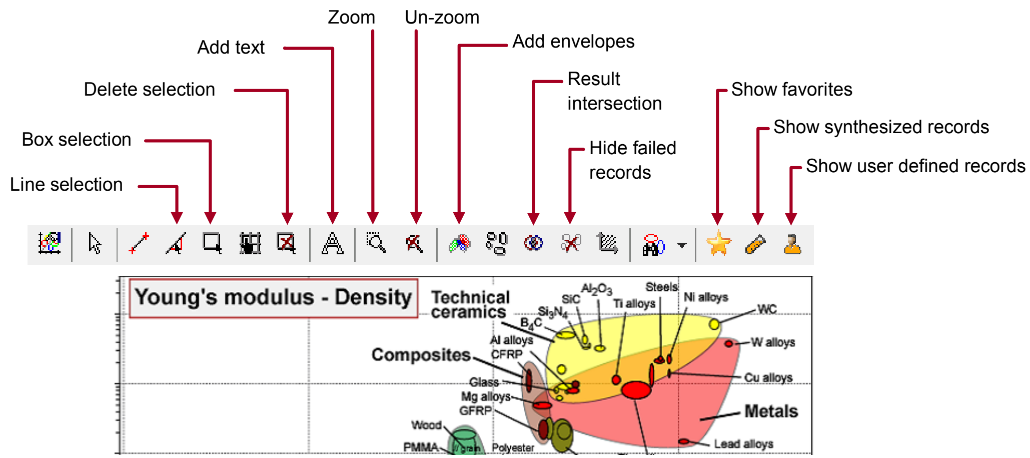


Figure A2. The Graph Stage toolbar in CES EduPack

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Open Access Resources include:

- Interactive Case Studies
- Getting Started Guides
- Materials Property Charts
- Engineering Data Booklets

You can register for a user name and password for these resources here:
www.grantadesign.com/education/resources

Other Resources Available:

- 24 PowerPoint lecture units
- Exercises with worked solutions
- Recorded webinars
- Posters
- White Papers
- Solution Manuals

GRANTA
TEACHING RESOURCES

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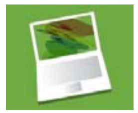
Granta's Teaching Resources website aims to support teaching of materials-related courses in Engineering, Science and Design.
The resources come in various formats and are aimed at different levels of student.

This resource is part of a set of open access resources created by Professor Mike Ashby to help introduce materials and materials selection to students.

The website also contains other resources donated by faculty at the 700+ universities and colleges worldwide using Granta's CES EduPack.

The teaching resource website contains both resources that require the use of CES EduPack and those that don't.



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