

**CES EduPack™ 2015**

# **CES EduPack User Manual and Getting Started Guide**

February 2015

**GRANTA**  
M A T E R I A L   I N S P I R A T I O N

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# 1 Overview

CES EduPack supports and enhances the teaching and learning of materials, engineering, design and sustainability. It provides a comprehensive database of materials and process information, powerful materials software tools, and a range of supporting textbooks, lectures, projects, and exercises.

With specialist Editions for specific disciplines, and three levels of the database and software to suit varying needs in all years of undergraduate study and postgraduate teaching, EduPack is a curriculum-wide resource. It is continually developed based on feedback from the global user community.

The CES EduPack software provides engaging ways for students to explore and understand the world of materials.

- **Become familiar with materials space**—with powerful tools to browse and search the information in CES EduPack databases.
- **Visualize properties**—charting tools help to develop understanding of how material families behave.
- **Match materials to applications**—for example, by applying a structured approach to materials selection; helps students to relate their learning to the world around them.
- **Dig into the underlying science**—encourage students to get to grips with the scientific principles through textbook-style 'science note' information and textbook links.
- **Evaluate environmental impact with the Eco Audit Tool**—explore key eco design concepts; try 'what if' scenarios.
- **Additional tools** are also available, such as the innovative Hybrid Synthesizer which allows investigation into the benefits of using hybrid materials.

## 1.1 Where to Find Help

You will be surprised at all the additional help and resources that can be accessed from CES EduPack.

### Getting Started



The **Installation Guide** is the starting point for anyone that has not yet installed CES EduPack.



If you have any questions or issues at this stage, you can refer to our **Student FAQs**.

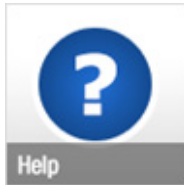


Or the **Educator FAQs**.

## Learning How EduPack Works



The **User Manual and Getting Started Guide**, as well as the **Video Tutorials**, are the best way to learn about the core functionality of the software.



The **In-Software Help** is accessed from the **Help** menu, or by pressing the **F1** key. As well as explaining the core functionality, it also includes useful references like the Tables of Materials Indices and glossaries of materials terms.

## Further Learning



The **Case Studies** were created by Professor Mike Ashby and follow the material selection methodology outlined in his book, *Material Selection for Mechanical Design*. They can be completed using CES EduPack.



You can find interactive case studies to practice your skills, ready-made Eco Audit project files, and fun databases on Granta's **Teaching Resources Website**.



The online books **CES InDepth** and **CES EduPack Concepts** explain the concepts of selection methodology and the CES EduPack databases.

## 2 Installation

### 2.1 Introduction

This part of the User Manual provides instructions for registering and installing your copy of the CES EduPack system.

#### System Requirements

To run the CES EduPack software you will need:

- A compatible Microsoft® Windows® operating system;  
Windows XP 32-bit SP3,  
Windows Vista 32-bit or 64-bit SP2,  
Windows 7 32-bit or 64-bit,  
Windows 8 32-bit or 64-bit.
- 4 GB of RAM.
- 4 GB of available hard disk space.
- Internet connection (for the Web Search functionality).
- Microsoft .NET Framework version 4.0 and ReportViewer 2010 SP1. For the French language installation you will also require the French language packs for both of these. If any of these are not already installed, you will be given the option to add them to the CES EduPack installation process.
- Administrator rights.

### 2.2 Licensing

#### Students

If you are a student installing this on your own computer then you do not need a license key. You have been given the files to install CES EduPack, either on a DVD or via a link to a network etc. *Check that you have been given a file called **info.dat** and that it is in the same folder as **setup.exe**.* If not, please ask your instructor for this file.

**For the Student FAQ page please go to**

**[www.grantadesign.com/education/support/FAQs/students.htm](http://www.grantadesign.com/education/support/FAQs/students.htm).**

#### Educators - Enrollment License

If you have an enrollment license - a time limited license for a group of students - then you need to make sure that you have been given a file called **info.dat** and that it is in the same folder as **setup.exe**. You do not need a license key. If you do not have this file, please ask your IT administrator or contact Granta Design.

#### Educators - Lab License

If you are setting up a perpetual or lab license, where the software is installed on a number of fixed computers, then you will need a license key. You will find this in on your software license agreement.

For the Educators FAQ page please go to [www.grantadesign.com/education/support/FAQs/educators.htm](http://www.grantadesign.com/education/support/FAQs/educators.htm).

#### Network Administrators

Please follow this link for information on installing the software over a network - [www.grantadesign.com/education/network](http://www.grantadesign.com/education/network).

For the Network Administration FAQ page please go to [www.grantadesign.com/education/support/FAQs/network.htm](http://www.grantadesign.com/education/support/FAQs/network.htm).

## 2.3 Running the Setup Program

If you have installed a previous version of CES EduPack, we recommend that you uninstall it before installing this version. To do so, use Add or Remove Programs in Windows Control Panel.

To install the software, run *setup.exe* and follow the instructions in the installation wizard. You can use **Cancel** or **Exit Setup** to quit the installation when they are displayed.

You can find a video of the installation process at [www.grantadesign.com/education/resources/videotutorials](http://www.grantadesign.com/education/resources/videotutorials).

## 3 Databases

Different databases are available depending on your installation.

The databases are split into *Introductory* - Level 1 and 2 databases, and *Advanced* - Level 3 databases, with different editions to cover specific areas of study e.g. Aerospace and Sustainability.

There are video Database Tours, to give you more information on the different levels and databases: <http://www.grantadesign.com/education/resources/videotutorials/2015/index.htm>.

### 3.1 Databases for Rational Materials Selection

The MaterialUniverse and ProcessUniverse data modules are used with CES EduPack to create high quality databases. They are designed for like-to-like comparisons across the whole spectrum of material and processing possibilities. Typical material databases do not allow this - the most common reasons being: 'holes in the data'; and different properties reported for different materials. This makes it difficult to compare different classes of materials.

Universe data modules solve the problem by conforming to strict database design principles. These principles are reviewed below, with reference to the MaterialUniverse data module.

#### **Complete spectrum represented**

The MaterialUniverse data module contains a representation of virtually every commercial engineering material in every class. This means that you can be sure that you have considered all material possibilities for any particular application.

#### **Each material represented only once**

Multiple instances of the same material from different producers are consolidated into one representative record. This reduces the complexity of the engineer's search for the best material.

#### **Property ranges**

Properties of real materials are seldom exact - there are inevitable variations from batch to batch and manufacturer to manufacturer. These variations are captured in a Universe data module by a range - the range may be small for a property such as density, but relatively large for price or toughness.

#### **Complete property set**

In a Universe data module, there is a value for every property on the datasheet. If the value is not known experimentally, it has been estimated by using intelligent estimating techniques based on well-established correlations between material properties, using their fundamental physics. These estimated values are denoted by a \* in the datasheet.

#### **Quality checks**

Granta has examined hundreds of material datasets over the years from various sources and, without exception, they contain errors - sometimes by as much as 1000%! To minimize errors in the Universe data modules, strict data checking procedures are used. These include checks that properties for specific material classes fall within acceptable ranges, and powerful science-based checks on the correlations between properties.

#### **Normalization**

All properties are presented in the same unit system, which can be chosen by the user. Properties that are reported in different ways for different materials classes are equivalenced to enable comparison.

#### **Hierarchy**

The carefully-constructed record hierarchy allows simple and rapid navigation to all records in the data module.

#### **The Result**

Applying these principles required a great amount of work in data collection and processing. The MaterialUniverse data module represents over 50 man-years of effort spread over a 15-year period.

The rewards of this effort are immediate and numerous with the MaterialUniverse and ProcessUniverse databases used in combination with the CES EduPack software.

**References**

The reference source is given at the bottom of the datasheet, to encourage students to question and research where the data comes from.

## 4 Getting Started with CES EduPack

The following exercises give an overview of CES EduPack and will teach you how to use the core functionality. The exercises in Chapter 5 go into further detail and explore some of the software's more specialized features. There is also comprehensive help file within the software that gives more detailed guidance, as well as case studies with loadable project files.

### 4.1 Brief Description of CES EduPack

The main tools in CES EduPack are:

- BROWSE      Explore the database and retrieve records via a hierarchical index or tree.
- SEARCH      Find information via a full-text search of records.
- SELECT      The central hub of CES EduPack, used to apply the Rational Material Selection methodology. A powerful selection engine that identifies records that meet an array of design criteria and enables trade-offs between competing objectives.
- CHART      Create charts and add formatting and labels to illustrate your point.
- ECO AUDIT      Quickly estimate the environmental impact of a product over its entire lifecycle and study *What If* design scenarios. The enhanced version also accounts for Secondary, Joining, and Finishing processes, and allows you to apply the same *What If* scenarios to the economic cost.
- HYBRID  
SYNTHESIZER      Explore the benefits of using different hybrid materials and structures; predict material performance and compare with standard materials.

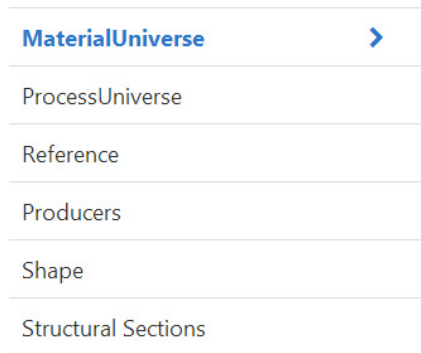
The following exercises cover the use and functionality of these tools.

## 4.2 Browsing and Searching

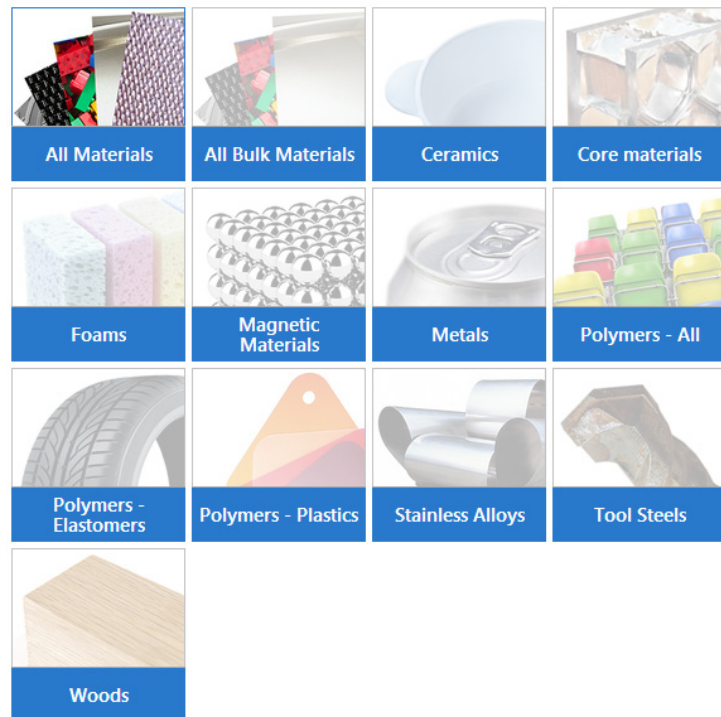
### Exercise 1 Opening the Database

If you have more than one database installed, CES EduPack will show the Databases dialog. The following exercises use the **MaterialUniverse** and **ProcessUniverse** tables, which are part of every Granta database.

#### 1. Select a table



#### 2. Filter by subset



The Edition Homepage will open, showing a list of the available tables and a graphic for each subset. Click on a subset name to show its description. Use the information icon next to the database name to show a detailed description.

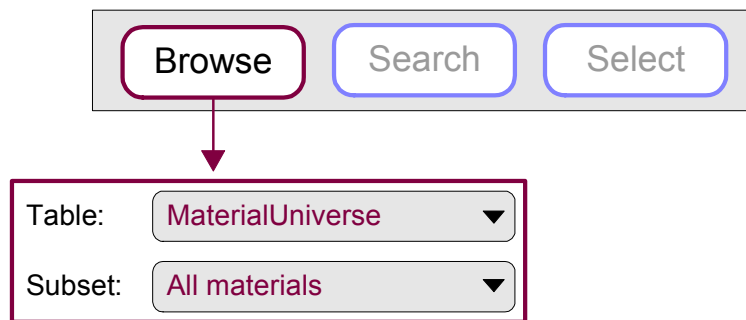
- Swap between the available subsets and see how they have different applications and data  
*Click on a subset in the Edition Homepage to select it. The information displayed is for the currently-selected subset. Notice that the **Browse** tree in the left pane updates to the currently selected subset.*

- Change to the PROCESSUNIVERSE table  
*Click on ProcessUniverse and notice that the **Browse** tree in the left pane updates to show the new table.*

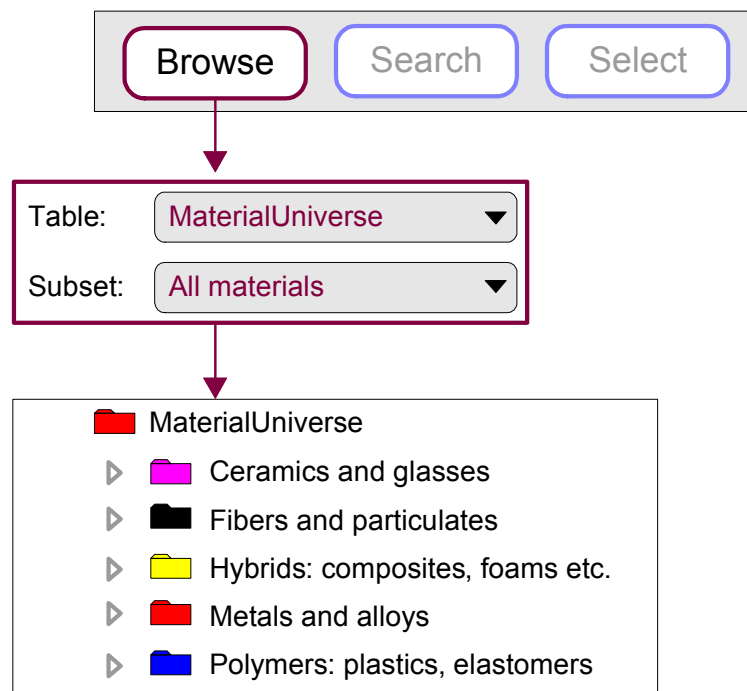
- CLOSE the HOMEPAGE  
*Click on the cross at the top of the Homepage tab. This page can be reopened at any time from **View menu - Home**.*

- Change to the MATERIALUNIVERSE table

*With the Homepage closed, navigate to different tables using the **Table** drop-down in the **Browse** pane.*



There are also links to online resources, for both students and educators, from the homepage.

**Exercise 2 Browse Materials**

Select the **Table** MaterialUniverse and the **Subset** All materials.

- Find a record for STAINLESS STEEL

- Find a record for CONCRETE

- Open the GENERIC record for POLYPROPYLENE

*Generic records are records at the folder level and give general information on the material, rather than data on a specific variant. Generic records have their own icon . Double-click to open.*

- Open a POLYPROPYLENE record

*Double-click on the record name in the tree*

Click on hyperlinked attribute names. In Level 1 and Level 2 databases, this will bring up a Science Note, giving details of the underlying science and calculations for the attribute. In Level 3 databases, this will bring up the design note, which provides background information on properties, test notes, and selection guidelines. From a design note, there will also be a link to the corresponding Science Note.

Right-click on the datasheet to see a context menu with further actions e.g., locate in Browse tree, copy the datasheet, print the datasheet, export the data to an FE package format.

The design note for Young's modulus:

## Young's modulus

Stiffness in tension (also called Tensile Modulus, Elastic Modulus, Modulus of Elasticity).

### Test notes

Young's modulus ( $E$ ) is the slope of the initial linear-elastic part of the stress-strain curve in tension.

### Material selection notes

Use to select materials with sufficient stiffness (high value) or sufficient compliance (low value).

Modulus in tension, flexure, and compression are similar for most materials so can be interchanged for approximate work.

Typical values:

|                                  |            |
|----------------------------------|------------|
| Flexible plastics and elastomers | < 1 GPa    |
| Unfilled plastics                | 1–4 GPa    |
| Reinforced plastics              | 5–25 GPa   |
| Ferrous metals                   | 70–250 GPa |
| Non-ferrous metals               | 10–310 GPa |
| Technical ceramics               | 20–700 GPa |
| Ceramics and glasses             | 1–120 GPa  |

Click to see [science note](#).

The corresponding Science Note from Level 3:

## *Young's modulus, shear modulus, bulk modulus, Poisson's ratio*

[Definition and measurement.](#)

[Drilling down: the origins of moduli.](#)

[Further reading.](#)

**Definition and measurement.** Figure 1 shows a typical tensile stress-strain curve. The initial part, up to the yield strength  $\sigma_y$  or elastic limit  $\sigma_{el}$ , defined under *Yield strength (elastic limit)*, is linear (Hooke's law), and it is elastic, meaning that the strain is recoverable – the material returns to its original shape when the stress is removed. Stresses above the elastic limit cause permanent deformation or fracture (see notes for [Yield strength \(elastic limit\)](#) and [Fracture toughness](#)).

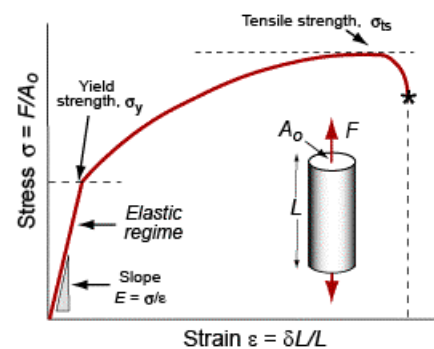
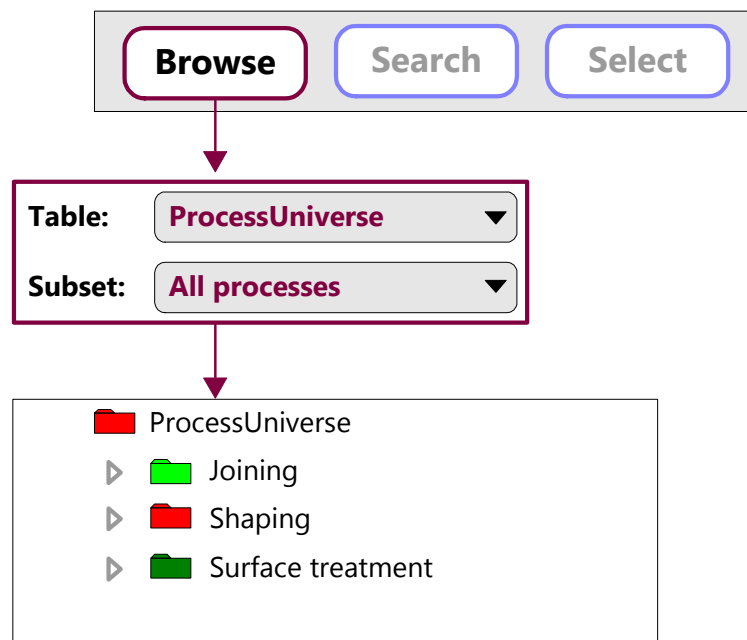


Figure 1. A tensile stress-strain curve.

Part of a datasheet for the material Polypropylene:

| <b>PP (Copolymer, UV stabilized)</b>                                                                                                                                                           |          |   |        |                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|---|--------|--------------------|
| <b>General properties</b>                                                                                                                                                                      |          |   |        |                    |
| <b>Designation</b>                                                                                                                                                                             |          |   |        |                    |
| Polypropylene (Copolymer, UV stabilized)                                                                                                                                                       |          |   |        |                    |
| <b>Composition overview</b>                                                                                                                                                                    |          |   |        |                    |
| <b>Composition (summary)</b>                                                                                                                                                                   |          |   |        |                    |
| copolymer of propylene (CH <sub>2</sub> -CH(CH <sub>3</sub> )) <sub>n</sub> and up to 7% ethylene (CH <sub>2</sub> CH <sub>2</sub> ) <sub>m</sub> or other comonomer + UV stabiliser additives |          |   |        |                    |
| <b>Price</b>                                                                                                                                                                                   |          |   |        |                    |
| Price                                                                                                                                                                                          | * 1.59   | - | 1.88   | USD/kg             |
| <b>Physical Properties</b>                                                                                                                                                                     |          |   |        |                    |
| Density                                                                                                                                                                                        | 899      | - | 909    | lb/in <sup>3</sup> |
| <b>Mechanical properties</b>                                                                                                                                                                   |          |   |        |                    |
| Young's modulus                                                                                                                                                                                | 1.23     | - | 1.26   | GPa                |
| Yield strength (elastic limit)                                                                                                                                                                 | 23.6     | - | 26.9   | MPa                |
| Tensile strength                                                                                                                                                                               | 23.4     | - | 24.6   | MPa                |
| Elongation                                                                                                                                                                                     | 139      | - | 865    | % strain           |
| Compressive strength                                                                                                                                                                           | * 29.5   | - | 31     | MPa                |
| Flexural strength (modulus of rupture)                                                                                                                                                         | * 31.3   | - | 35.9   | MPa                |
| Shear modulus                                                                                                                                                                                  | * 0.438  | - | 0.449  | GPa                |
| Bulk modulus                                                                                                                                                                                   | * 2.26   | - | 2.32   | GPa                |
| Poisson's ratio                                                                                                                                                                                | * 0.405  | - | 0.413  |                    |
| Hardness - Vickers                                                                                                                                                                             | * 7.37   | - | 7.74   | HV                 |
| Fatigue strength at 10 <sup>7</sup> cycles                                                                                                                                                     | * 9.36   | - | 9.83   | MPa                |
| Fracture toughness                                                                                                                                                                             | * 1.36   | - | 1.43   | ksi                |
| Mechanical loss coefficient (tan delta)                                                                                                                                                        | * 0.0312 | - | 0.0328 |                    |
| <b>Thermal properties</b>                                                                                                                                                                      |          |   |        |                    |
| Melting point                                                                                                                                                                                  | * 145    | - | 153    | °C                 |
| Glass temperature                                                                                                                                                                              | -24      | - | -16    | °C                 |
| Maximum service temperature                                                                                                                                                                    | * 64.6   | - | 81.7   | °C                 |
| Minimum service temperature                                                                                                                                                                    | * -25    | - | -10    | °C                 |
| Thermal conductivity                                                                                                                                                                           | * 0.197  | - | 0.205  | W/m °C             |
| Specific heat capacity                                                                                                                                                                         | * 0.448  | - | 0.457  | J/kg °C            |
| Thermal expansion coefficient                                                                                                                                                                  | 65.8     | - | 67.4   | µstrain/°C         |

- Find PROCESSES that can shape POLYPROPYLENE using the ProcessUniverse LINK at the bottom of the datasheet.

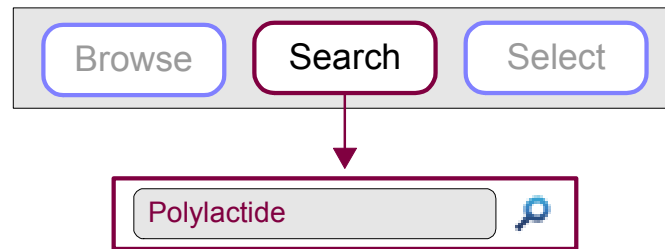
**Exercise 3 Browse Processes**

Browse ProcessUniverse: All processes

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

### Exercise 4 The Search Facility

- Find the material POLYLACTIDE



The search term is highlighted in records opened from the search results.

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

Note: The folder name is also included in the search. If the term appears in a folder name, all records under that folder will be returned; for example, a search for **ceramic** would return all records in the folder named **Ceramic**.

Wildcards are automatically added to the end of each search term.

- Enter the search term ALUM

*Records for or containing **Alumina** and **Aluminum** are returned.*

- The following search operators are available:

|                      |                                                                                                                                                                                 |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AND</b>           | Finds records containing both the search terms, so <b>steel AND alloy</b> returns only records containing both the words <b>steel</b> and <b>alloy</b>                          |
| <b>OR</b>            | Finds records containing either search term, so <b>steel OR alloy</b> returns all records that contain <b>steel</b> , <b>alloy</b> , or <b>both</b>                             |
| <b>NOT</b>           | Finds records containing the first search term, but not the second, so <b>steel NOT alloy</b> returns only records with the word <b>steel</b> but without the word <b>alloy</b> |
| <b>Phrase Search</b> | Finds the exact search term, so <b>"steel alloy"</b> will return only records containing the exact phrase <b>steel alloy</b>                                                    |
| <b>Parentheses</b>   | Used to group search terms, so <b>iron AND (ore OR cast)</b> will return the records containing <b>iron</b> and containing either <b>ore</b> , <b>cast</b> , or <b>both</b>     |
| <b>Wildcards</b>     | Use <b>?</b> as a wildcard single character, or <b>*</b> as a wildcard representing any number of characters (cannot be used as the first character in a search string)         |

Note: AND operators are automatically added when a search has two or more terms and no other operators have been entered.

## 4.3 Material Selection

### Exercise 5 Selection Using a Limit Stage

- Find materials with:

|                          |                           |
|--------------------------|---------------------------|
| MAX. SERVICE TEMPERATURE | > 200 °C                  |
| THERMAL CONDUCTIVITY     | > 25 W/m.°C               |
| ELECTRICAL RESISTIVITY   | > 1e15 $\mu\text{ohm.cm}$ |



Use the limit bars for guidance on suitable values. Enter the limits – minimum or maximum as appropriate – and click **Apply**. If a reference record is set, its values for each property will be shown to the right of the min/max entry boxes.

Example results: Aluminum nitride, Alumina, Silicon nitride.

Some properties have discrete values, rather than numeric ranges.

- Edit this limit stage and search for materials with non-opaque TRANSPARENCY. Under **Optical Properties**, refine by transparency using the drop-down and tick **Translucent**, **Transparent**, and **Optical quality**. Click **Apply**. Example results: Alumina (translucent) and Diamond.

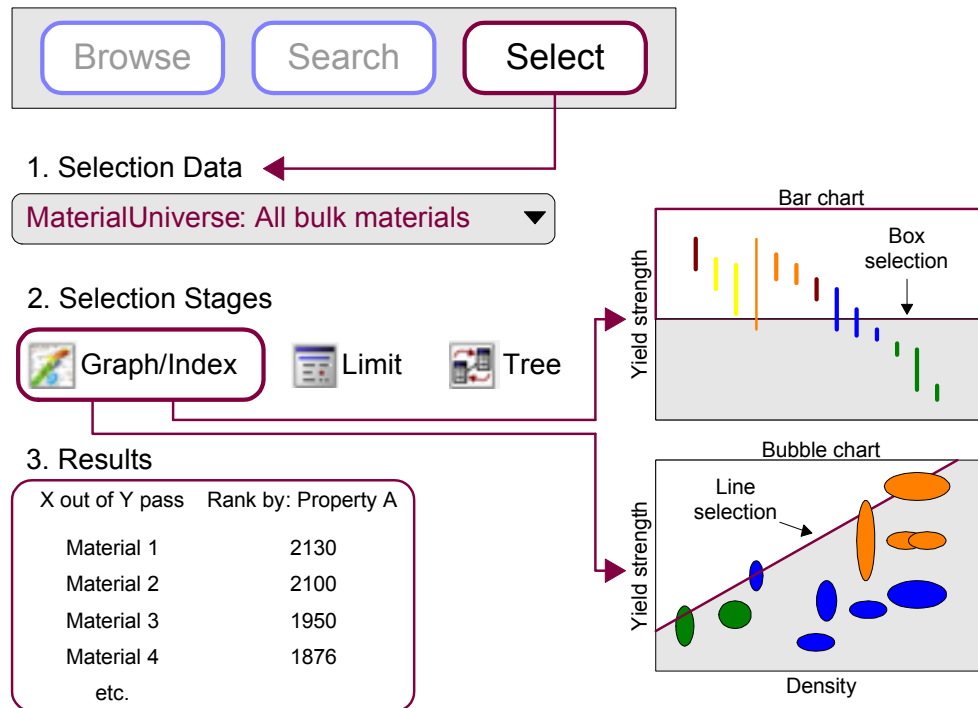
- DELETE THIS STAGE

## Exercise 6 Selection Using a Graph Stage

When plotted on a Graph Stage, records can also be filtered using the charting Box and Line Selection tools. This provides a more qualitative approach to filtering.

- Make a BAR CHART of YIELD STRENGTH ( $\sigma_y$ )

Set the y-axis to **Yield strength (elastic limit)**.



- Use a BOX SELECTION to find materials with high values of YIELD STRENGTH

Click **Box Selection** , then click-drag-release to define the box.

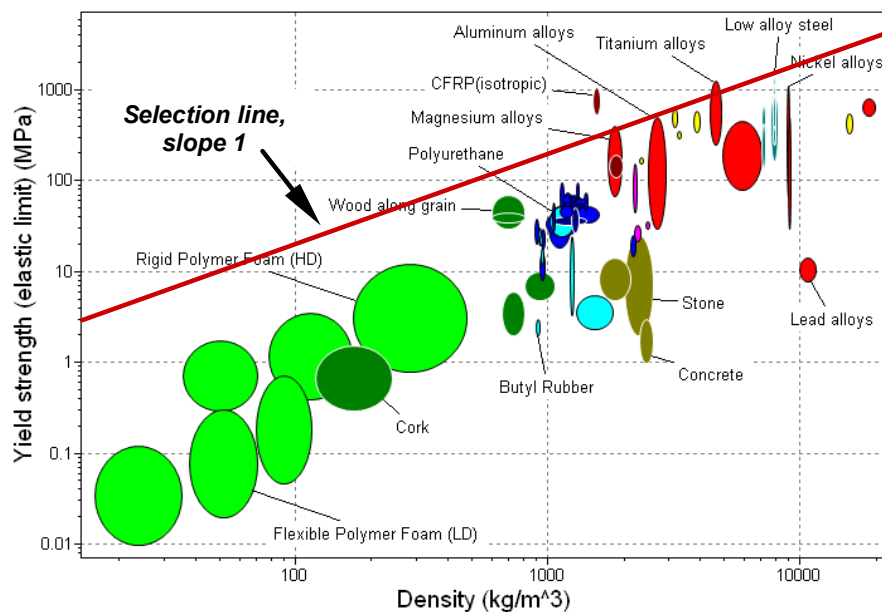
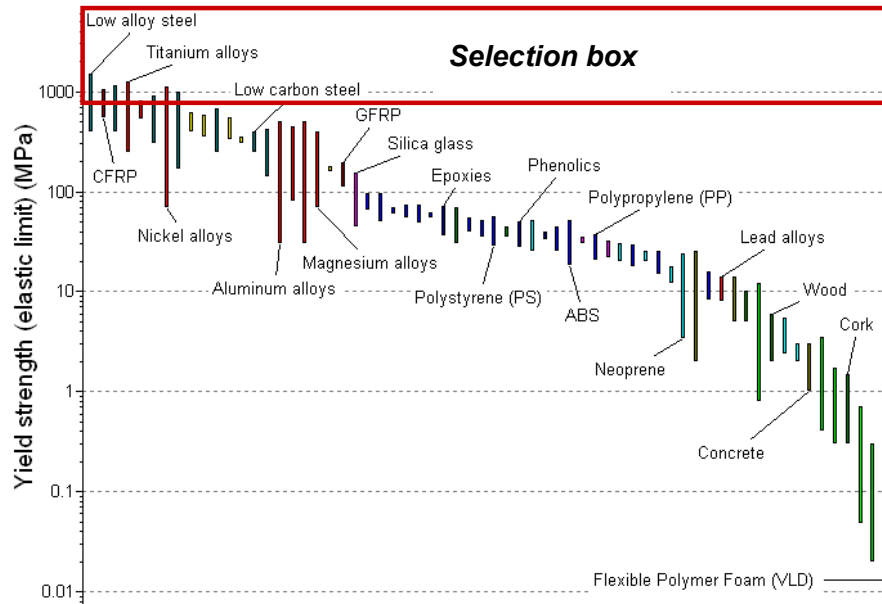
- Add DENSITY ( $\rho$ ) to the other axis

Either: highlight Stage 1 in Selection Stages, right-click and choose **Edit Stage** from the menu; or double-click the axis to edit.

- Use a BOX SELECTION to find materials with high STRENGTH and low DENSITY

- Use a LINE SELECTION to find materials with high values of the specific strength  $\sigma_y / \rho$

Click **Gradient-Line Selection** , then enter slope in the dialog, in this case 1. Click on the graph to position the line through a particular point. Click above or below the line to select an area, in this case above the line for high values of  $\sigma_y / \rho$ . Drag the line upwards to refine the selection to fewer materials.



- Rank the results by specific strength (YIELD STRENGTH / DENSITY)

*Rank by Stage 1: Performance Index and click on results column to reverse the order.*

*Example results: CFRP, Titanium alloys, Magnesium alloys.*

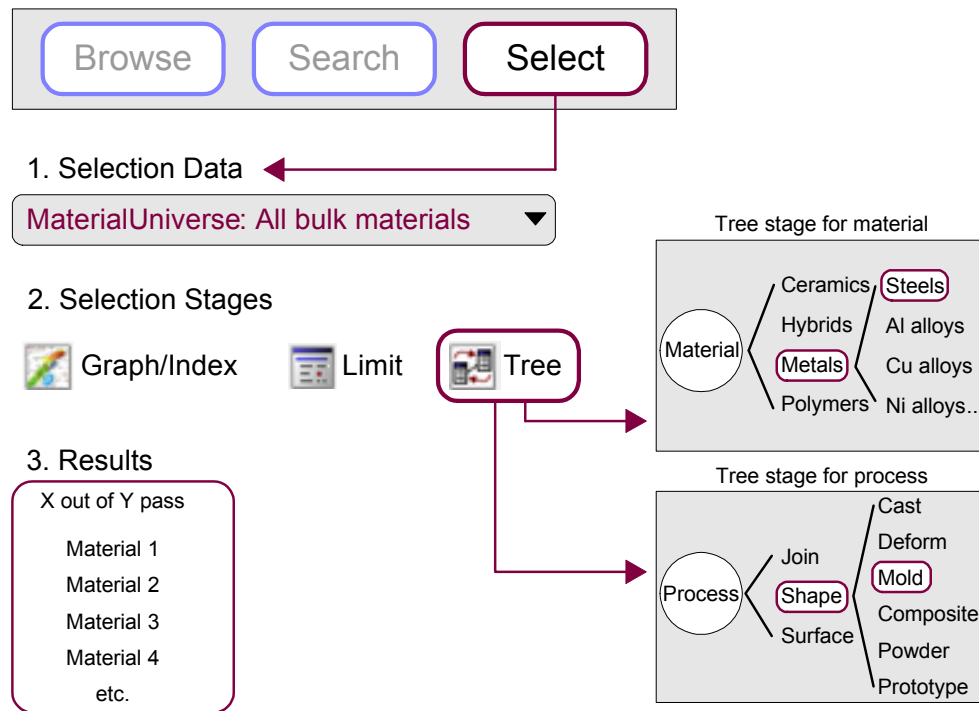
- DELETE ALL STAGES

Using a Tree Stage, records can be filtered based on their links to records in other data tables, or based on the database hierarchy (tree).

### Exercise 7 Selection Using a Tree Stage

- Find materials that can be MOLDED

In the Tree Stage window, select ProcessUniverse, navigate to **Molding**, and click **Insert** followed by **OK**.



- DELETE THIS STAGE

- Find processes to join STEELS

Select Processes: Joining processes. In the Tree Stage window, select MaterialUniverse, expand **Metals and alloys** in the tree, select **Ferrous**, and click **Insert** followed by **OK**.

- DELETE THIS STAGE

## Exercise 8 Combining Filtering and Charting Tools

Select Level 3 MaterialUniverse: All bulk materials.

- Find materials with:

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

Add a Limit Stage with three criteria.

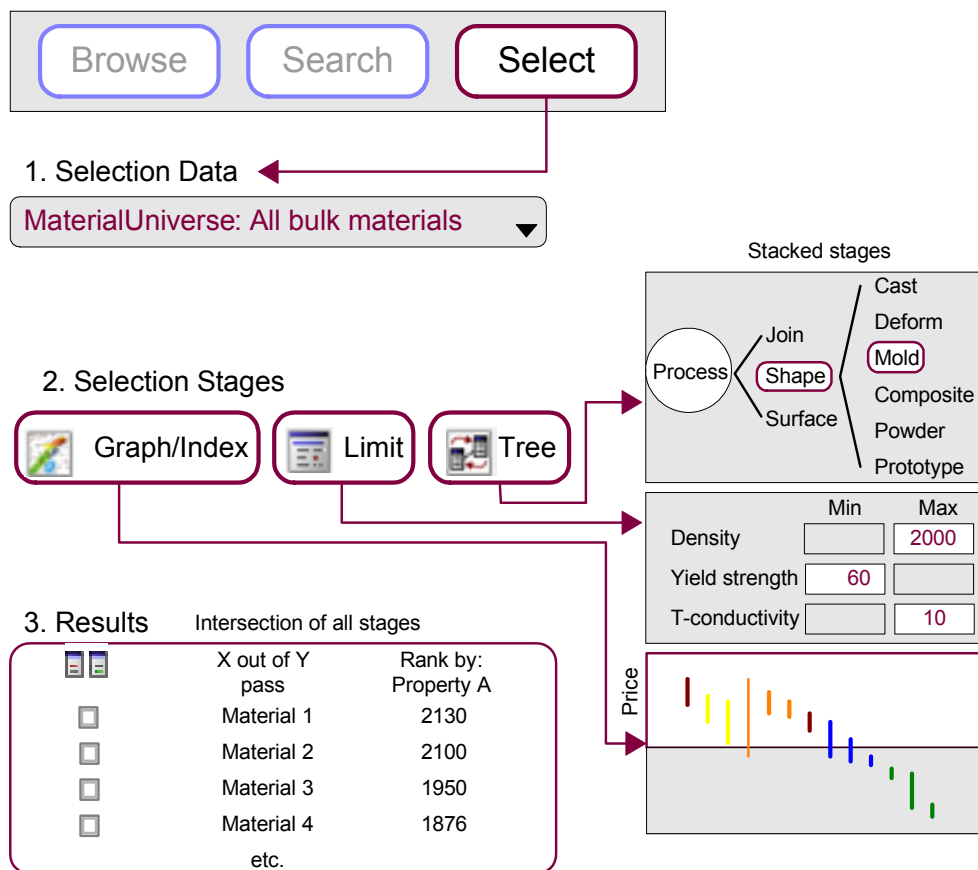
- Filter the results to find those that can be THERMOFORMED

Add a Tree Stage and select ProcessUniverse - Shaping - Molding.

- Rank the results by PRICE

Add a Graph Stage with a bar chart of **Price**. On the Graph Stage, all materials that fail one or more stages are grayed out. The **Results** pane shows the materials that pass all stages.

Example results, lowest PRICE first: PET-GF, PLA, PET ...



**Exercise 9 Finding Supporting Information**

The following exercise requires an Internet connection.

CES EduPack translates the material ID to search strings compatible with a group of high-quality material and process information sources and delivers the hits. Many of the sources require a subscriber-based password. The ASM source is particularly recommended.

- Search the web to find more information on PET  
*With the **PET** datasheet open, click on **Search Web**.*

## 4.4 Process Selection

### Exercise 10 Selecting Processes

Select Level 3 ProcessUniverse: Shaping processes.

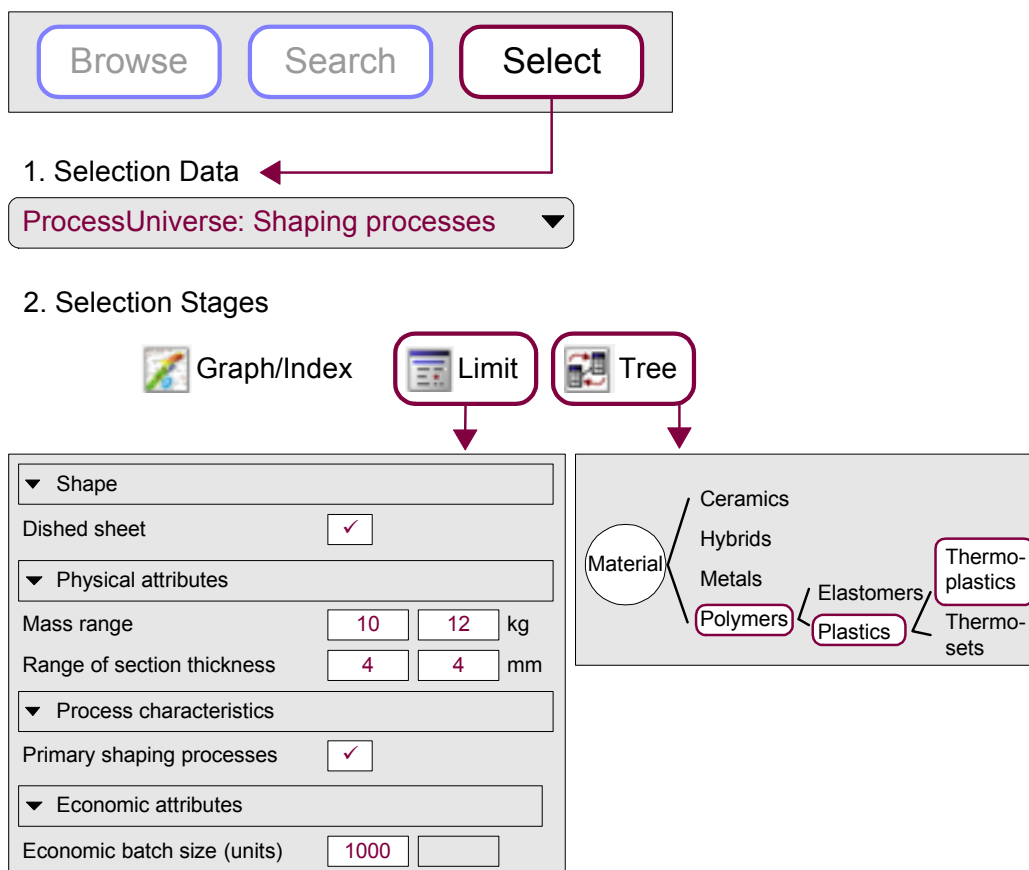
- Find PRIMARY SHAPING PROCESSES to make a component that has:

|                     |              |
|---------------------|--------------|
| SHAPE               | Dished sheet |
| MASS                | 10 - 12 kg   |
| SECTION THICKNESS   | 4 mm         |
| ECONOMIC BATCH SIZE | > 1000       |

Add a Limit Stage with five criteria.

- Refine this search to only include THERMOPLASTIC materials  
Add a Tree Stage and select MaterialUniverse - Polymers - Plastics - Thermoplastics.

Example results: Thermoplastic composite molding, Spray-up, Rotational molding, Compression molding.



## 4.5 Saving, Copying, and Report Writing

### Exercise 11 Saving, Exporting, and Copying

- Save the project

Go to the **File** menu - **Save Project**. Give the project a filename and directory location; the project will be saved with the file extension **.ces**.

Charts, records, and results lists can be copied and pasted into a word processing application.

- Generate a chart. Copy and paste the chart into a document

Click on the chart. Either: right-click on the chart and select **Copy**; or press **CTRL+C** to copy the chart to your clipboard. Paste from your clipboard to the document.

- SEARCH for a record and display the datasheet. Copy and paste the datasheet into a document

- GENERATE a RESULTS list using SELECT. Copy and paste the full list into a document

Right-click in **Results** and click **Select all**. Either: right-click on the highlighted list and select **Copy**; or press **CTRL+C** once the list has been highlighted.

- Copy individual results from the results list into a document

Use **SHIFT+click** or **CTRL+click** to highlight selected records.

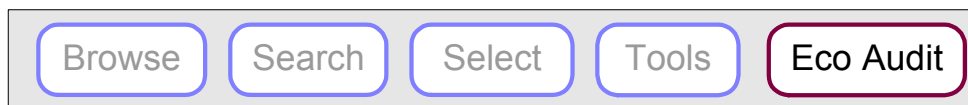
- Try editing the document you have created

## 4.6 Eco Audit

The Eco Audit Tool estimates the energy used and CO<sub>2</sub> 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.

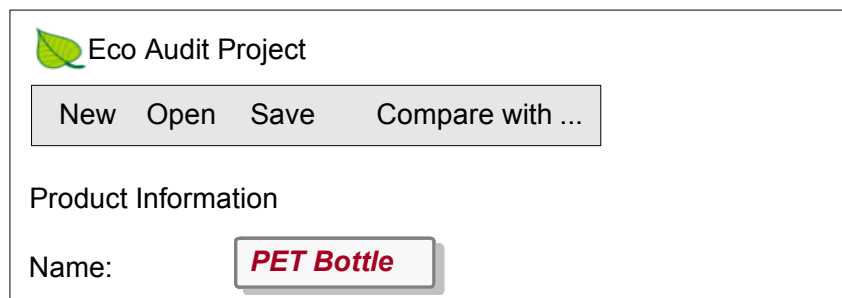
A brand of bottled mineral water is sold in 1 liter PET bottles with polypropylene caps. A bottle weighs 40 grams; the cap 1 gram. Bottles and caps are molded, filled, and transported 550 km from the French Alps to England by 14 tonne truck, refrigerated for 2 days and then sold. The overall life of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

An example product file for this case study is installed with CES EduPack in the **Samples** folder, with the filename **Bottle mineral water.prd**.



### Product Definition

The following details how the example product file has been created.



For an explanation of the calculations used at each stage, click the Help icon  in the heading.

## 1. Material, manufacture, and end of life

Bill of materials (BoM) and primary processing techniques.

| Quantity | Component name | Material                                                                                                                                                                                                                                                                                                                                                                                                   | Recycle content      | Primary process                | Mass (kg) | End of life                                                       |
|----------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|--------------------------------|-----------|-------------------------------------------------------------------|
| 100      | Bottle         | PET                                                                                                                                                                                                                                                                                                                                                                                                        | 0%                   | Molding                        | 0.04      | Recycle                                                           |
|          |                | <div> MaterialUniverse <ul style="list-style-type: none"> <li>Ceramics and glasses</li> <li>Hybrids: composites etc</li> <li>Metals and alloys</li> <li>Polymers and elastomers <ul style="list-style-type: none"> <li>Elastomers</li> <li>Polymers <ul style="list-style-type: none"> <li>Thermoplastics <ul style="list-style-type: none"> <li>PET</li> </ul> </li> </ul> </li> </ul> </li> </ul> </div> | <div> 0% 100% </div> | <div> Molding Extrusion </div> |           | <div> Landfill Combust Downcycle Recycle Re-engineer Reuse </div> |
| 100      | Cap            | PP                                                                                                                                                                                                                                                                                                                                                                                                         | 0%                   | Molding                        | 0.001     | Combust                                                           |
| 100      | Water          |                                                                                                                                                                                                                                                                                                                                                                                                            |                      |                                | 1         |                                                                   |

## 2. Transport

Transportation from site of manufacture to point of sale.

| Stage Name                      | Transport type                                                                   | Distance (km) |
|---------------------------------|----------------------------------------------------------------------------------|---------------|
| Bottling plant to point of sale | 14 tonne truck                                                                   | 550           |
|                                 | <div> Sea freight Rail freight 14 tonne truck Air freight – long haul ... </div> |               |

## 3. Use

### Product Life and Location Use

Product life: 1 years

Country electric mix: United Kingdom

France
Germany
United Kingdom
...

## Static Mode

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

☒ Product uses the following energy:

Energy input and output: *Electric to mechanical (electric motors)* ▼

Power rating: *0.12* *kW* ▼

Usage: *2* days per year

Usage: *2* hours per day

Fossil fuel to thermal, enclosed system

Fossil fuel to electric

Electric to thermal

**Electric to mechanical (electric motors)**

...

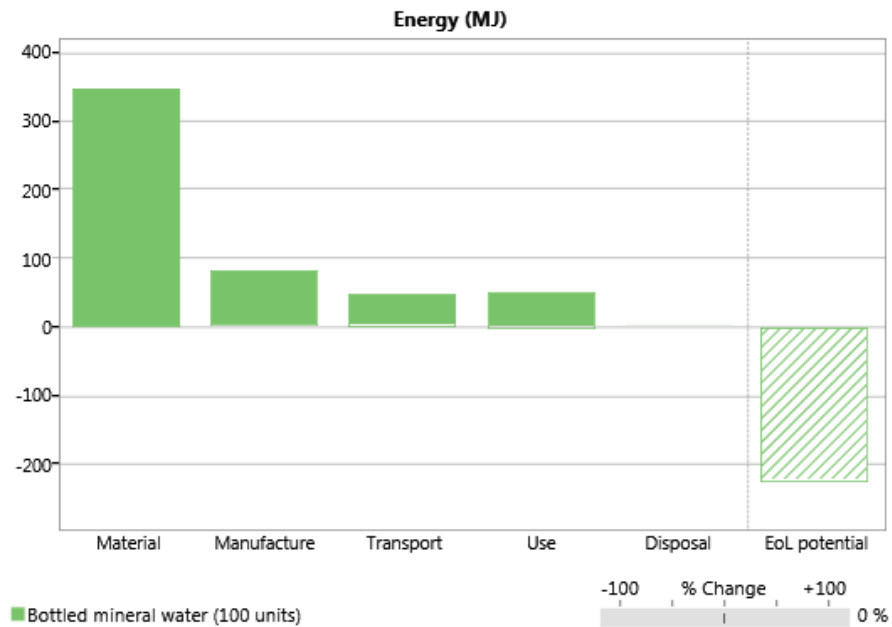
## 4. Report

### Summary chart

enables rapid identification of the dominant life phase.

Toggle between views of energy usage or CO<sub>2</sub> footprint.

Energy CO<sub>2</sub>



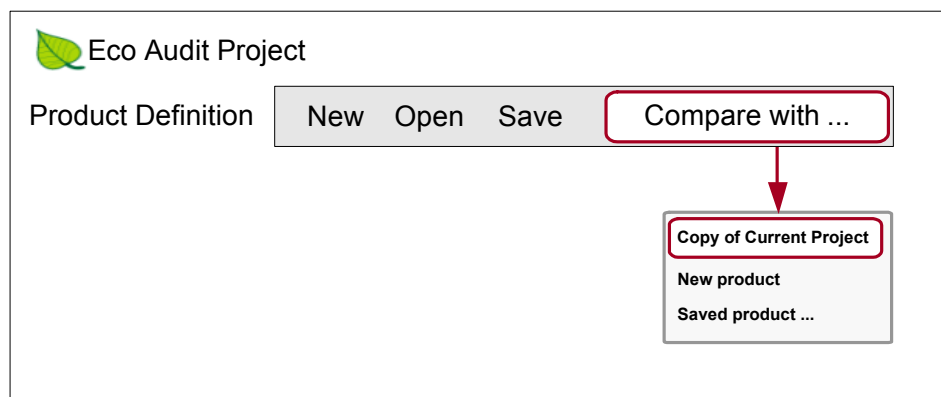
The chart shows that, in this project, Material is the dominant life phase. Each life phase can be clicked to show guidance on strategies to reduce its impact.

#### ***Detailed report***

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

## Exercise 12 Compare Eco Audits

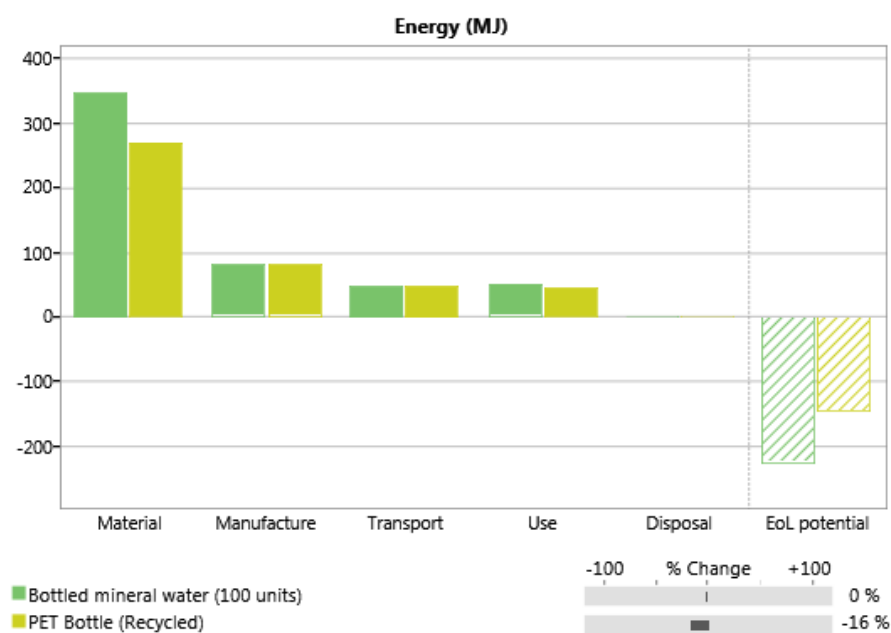
- Create a copy of the current product for comparison  
Click **Compare with** and select **Copy of current product**.



- Set the following values in for the new product:

|                  |                       |
|------------------|-----------------------|
| NAME             | PET Bottle (Recycled) |
| RECYCLED CONTENT | 35%                   |

- Generate the SUMMARY CHART



The first life energy (not including EoL potential) is reduced by 16%.

Note: The chart can be copied into a document or printed using **Copy** and **Print** at the top of the chart window.

### Exercise 13 Saving and Exporting

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

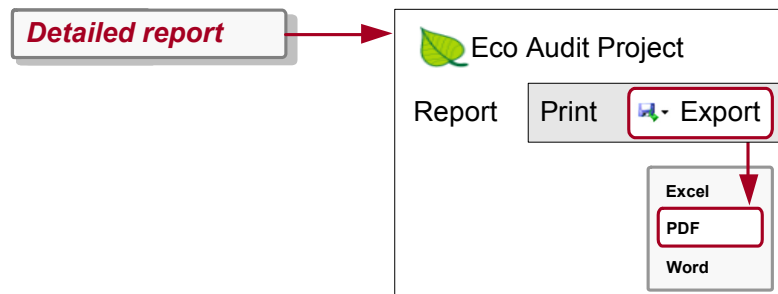
- SAVE the product definition



- GENERATE the Eco Audit report

- EXPORT the report as a PDF

*Note: You will require a PDF reader such as Adobe Reader to view the exported report.*



## 4.7 Hybrid Synthesizer

*The Hybrid Synthesizer is a tool available in some editions of CES EduPack. If the Synthesizer is in your edition, it can be found on the **Tools** menu.*

Hybrid materials and structures combine the benefits of two or more materials to produce new materials that exhibit unique combinations of properties. For example, both composite materials and sandwich panels are commonly used in lightweight structures. The Hybrid Synthesizer enables the performance of these structures to be predicted and compared with other materials in the database.

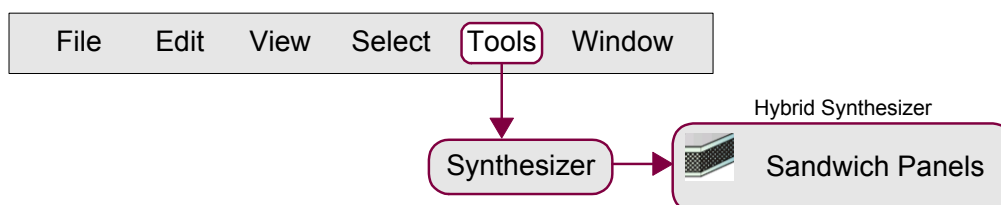
It is also possible to create your own material models. There is a Model Writer's Guide available from within the Hybrid Synthesizer tool, and a White Paper that can be found in the Student Resources section of the software help.

### Exercise 14 Sandwich Panels Model

Select MaterialUniverse: All bulk materials

- Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY ( $\rho$ )  
As in Exercise 6.

- Use the SANDWICH PANELS MODEL to create synthesized records for a family of hybrid materials  
Go to the **Tools** menu - **Synthesizer**. In the dialog, select **Balanced Sandwich Panels**.



- Set the SOURCE RECORD values:

|            |                                        |
|------------|----------------------------------------|
| FACE-SHEET | Aluminum, 6061, wrought, T6            |
| CORE       | Polymethacrylimide foam (rigid, 0.200) |

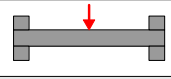
Click **Browse** and locate the records in the tree.

- Leave the default values for MODEL VARIABLES and MODEL PARAMETERS

- Set the RECORD NAMING values:

|            |          |
|------------|----------|
| FACE-SHEET | Al       |
| CORE       | Rohacell |

**Balanced Sandwich Panels**

|                                     |                                                                                                                 |    |                      |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------|----|----------------------|
| <b>Source Records</b>               |                                                                                                                 |    |                      |
| Face-sheet                          | Aluminum, 6061, wrought, T6                                                                                     |    |                      |
| Core                                | Polymethacrylimide foam (rigid, 0.200)                                                                          |    |                      |
| <b>Model Variables</b>              |                                                                                                                 |    |                      |
| Face-sheet thickness                | 0.05 - 5                                                                                                        | mm | Number of values: 10 |
| Core thickness                      | 20                                                                                                              | mm | Number of values: 3  |
| <b>Model Parameters</b>             |                                                                                                                 |    |                      |
| Support and load conditions         |  Built-in ends<br>Central load |    |                      |
| Span                                | 10                                                                                                              | m  |                      |
| <b>Record Naming</b>                |                                                                                                                 |    |                      |
| Face-sheet                          | Al                                                                                                              |    |                      |
| Core                                | Rohacell                                                                                                        |    |                      |
| This model will generate 10 records |                                                                                                                 |    | <b>Create</b>        |

- CREATE the synthesized records

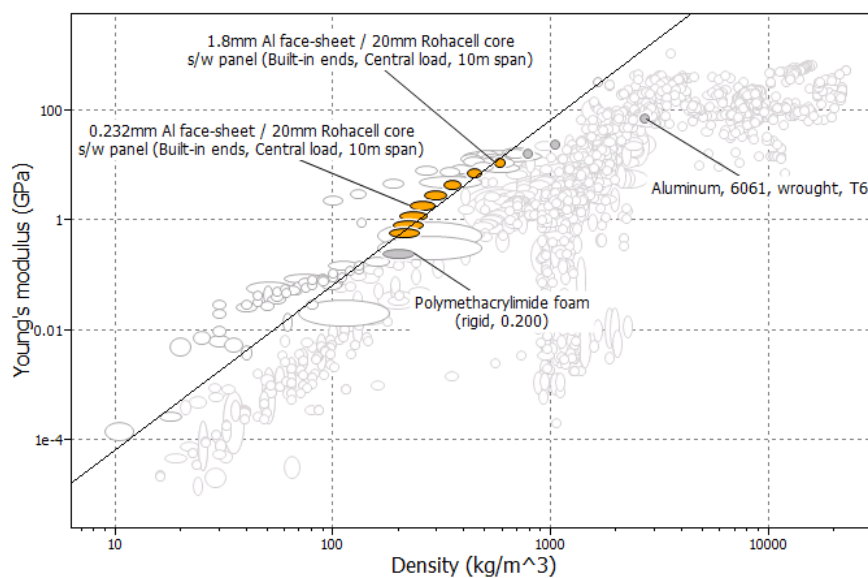
Click **Create** and then **Finish**. The new synthesized records will be shown on the **Graph Stage**.

Note: The Help icon  in the Synthesizer dialog opens a list of the calculations used for the current model type.

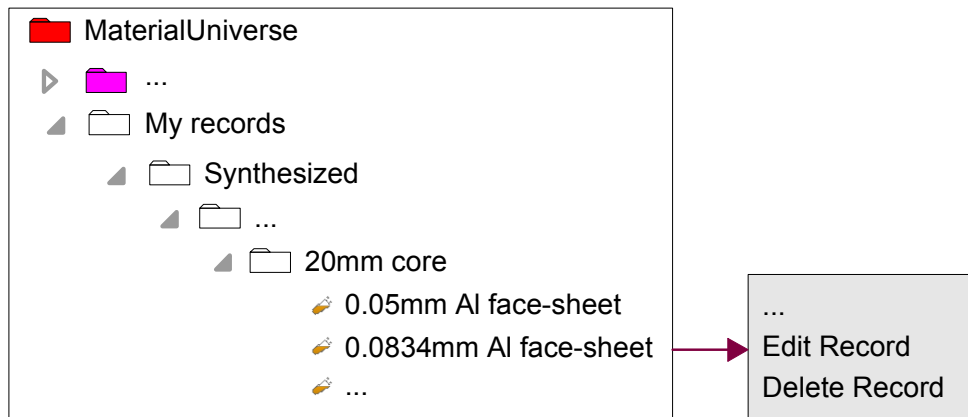
- Plot a LINE SELECTION corresponding to a lightweight, stiff panel in bending  $p/E_f^{1/3}$

Click **Gradient-Line Selection**  and enter a slope of 3.

- Add labels to the source records and some of the synthesized records

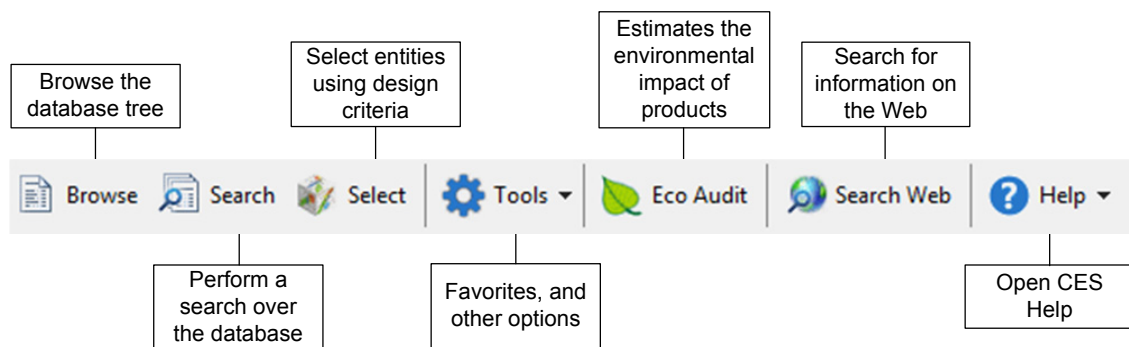


Synthesized records appear on the Browse tree under **My Records** and may be edited or deleted in a similar way to User Defined records.

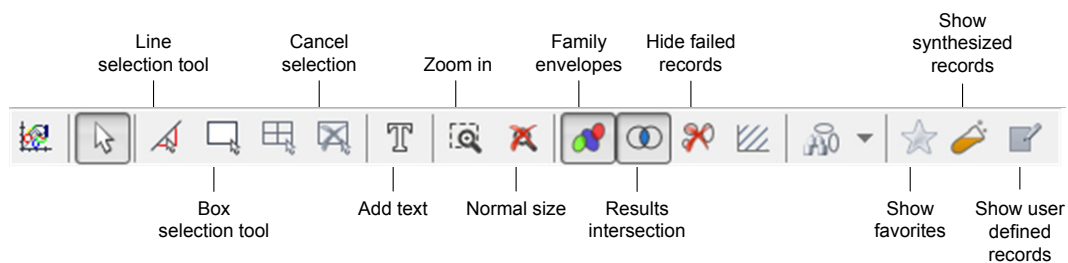


## 5 Toolbars and General Information

### Standard Toolbar



### Graph Stage Toolbar



### File Types

|       |                                   |
|-------|-----------------------------------|
| *.gdb | Granta Database file              |
| *.ces | CES EduPack Project file          |
| *.cet | Selection Template file           |
| *.frl | Favorites file                    |
| *.prd | Eco Audit Product Definition file |

**Physical Constants and Conversion of Units**

|                                  |                                              |
|----------------------------------|----------------------------------------------|
| Absolute zero temperature        | -273.2°C                                     |
| Acceleration due to gravity, g   | 9.807 m/s <sup>2</sup>                       |
| Avogadro's number N <sub>A</sub> | 6.022 x 10 <sup>23</sup>                     |
| base of natural logarithm, e     | 2.718                                        |
| Boltzmann's constant, k          | 1.381 x 10 <sup>-23</sup> J/K                |
| Faraday's constant, k            | 9.648 x 10 <sup>4</sup> C/mol                |
| Gas constant, R                  | 8.314 J/mol/K                                |
| Planck's constant, h             | 6.626 x 10 <sup>-34</sup> Js                 |
| Velocity of light in a vacuum, c | 2.998 x 10 <sup>8</sup> m/s                  |
| Volume of perfect gas at STP     | 22.41 x 10 <sup>-3</sup> m <sup>3</sup> /mol |

|                                   |                                                   |                                                                                    |
|-----------------------------------|---------------------------------------------------|------------------------------------------------------------------------------------|
| Angle, $\theta$                   | 1 rad                                             | 57.30°                                                                             |
| Density, $\rho$                   | 1 lb/ft <sup>3</sup>                              | 16.03 kg/m <sup>3</sup>                                                            |
| Diffusion coefficient, D          | 1 cm <sup>2</sup> /s                              | 1.0 x 10 <sup>-4</sup> m <sup>2</sup> /s                                           |
| Energy, U                         | See below                                         |                                                                                    |
| Force, F                          | 1 kgf<br>1 lbf<br>1 dyne                          | 9.807 N<br>4.448 N<br>1.0 x 10 <sup>-5</sup> N                                     |
| Length, l                         | 1 ft<br>1 inch<br>1 Å                             | 304.8 mm<br>25.40 mm<br>0.1 nm                                                     |
| Mass, M                           | 1 tonne<br>1 short ton<br>1 long ton<br>1 lb mass | 1000 kg<br>908 kg<br>1107 kg<br>0.454 kg                                           |
| Power, P                          | See below                                         |                                                                                    |
| Stress, $\sigma$                  | See below                                         |                                                                                    |
| Specific Heat, Cp                 | 1 cal/gal.°C<br>1 Btu/lb.°F                       | 4.188 kJ/kg.°C<br>4.187 kJ/kg.°C                                                   |
| Stress Intensity, K <sub>1c</sub> | 1 ksi √in                                         | 1.10 MN/m <sup>3/2</sup>                                                           |
| Surface Energy, $\gamma$          | 1 erg/cm <sup>2</sup>                             | 1 mJ/m <sup>2</sup>                                                                |
| Temperature, T                    | 1°F                                               | 0.556°K                                                                            |
| Thermal Conductivity, $\lambda$   | 1 cal/s.cm.°C<br>1 Btu/h.ft.°F                    | 418.8 W/m.°C<br>1.731 W/m.°C                                                       |
| Volume, V                         | 1 Imperial gall<br>1 US gall                      | 1.546 x 10 <sup>-3</sup> m <sup>3</sup><br>3.785 x 10 <sup>-3</sup> m <sup>3</sup> |
| Viscosity, $\eta$                 | 1 poise<br>1 lb ft.s                              | 0.1 N.s/m <sup>2</sup><br>0.1517 N.s/m <sup>2</sup>                                |

**Conversion of Units - Stress and Pressure**

|                                | <b>MPa</b>            | <b>dyn/cm<sup>2</sup></b> | <b>lb/in<sup>2</sup></b> | <b>kgf/mm<sup>2</sup></b> | <b>bar</b>            | <b>long ton/in<sup>2</sup></b> |
|--------------------------------|-----------------------|---------------------------|--------------------------|---------------------------|-----------------------|--------------------------------|
| <b>MPa</b>                     | 1                     | $10^7$                    | $1.45 \times 10^2$       | 0.102                     | 10                    | $6.48 \times 10^{-2}$          |
| <b>dyn/cm<sup>2</sup></b>      | $10^{-7}$             | 1                         | $1.45 \times 10^{-5}$    | $1.02 \times 10^{-8}$     | $10^{-6}$             | $6.48 \times 10^{-9}$          |
| <b>lb/in<sup>2</sup></b>       | $6.89 \times 10^{-3}$ | $6.89 \times 10^4$        | 1                        | $703 \times 10^{-4}$      | $6.89 \times 10^{-2}$ | $4.46 \times 10^{-4}$          |
| <b>kgf/mm<sup>2</sup></b>      | 9.81                  | $9.81 \times 10^7$        | $1.42 \times 10^3$       | 1                         | 98.1                  | $63.5 \times 10^{-2}$          |
| <b>bar</b>                     | 0.10                  | $10^6$                    | 14.48                    | $1.02 \times 10^{-2}$     | 1                     | $6.48 \times 10^{-3}$          |
| <b>long ton/in<sup>2</sup></b> | 15.44                 | $1.54 \times 10^8$        | $2.24 \times 10^3$       | 1.54                      | $1.54 \times 10^2$    | 1                              |

**Conversion of Units - Energy**

|               | <b>J</b>               | <b>erg</b>             | <b>cal</b>             | <b>eV</b>             | <b>Btu</b>             | <b>ft lbf</b>          |
|---------------|------------------------|------------------------|------------------------|-----------------------|------------------------|------------------------|
| <b>J</b>      | 1                      | $10^7$                 | 0.239                  | $6.24 \times 10^{18}$ | $9.48 \times 10^{-4}$  | 0.738                  |
| <b>erg</b>    | $10^{-7}$              | 1                      | $2.39 \times 10^{-8}$  | $6.24 \times 10^{11}$ | $9.48 \times 10^{-11}$ | $7.38 \times 10^{-8}$  |
| <b>cal</b>    | 4.19                   | $4.19 \times 10^7$     | 1                      | $2.61 \times 10^{19}$ | $3.97 \times 10^{-3}$  | 3.09                   |
| <b>eV</b>     | $1.60 \times 10^{-19}$ | $1.60 \times 10^{-12}$ | $3.38 \times 10^{-20}$ | 1                     | $1.52 \times 10^{-22}$ | $1.18 \times 10^{-19}$ |
| <b>Btu</b>    | $1.06 \times 10^3$     | $1.06 \times 10^{10}$  | $2.52 \times 10^2$     | $6.59 \times 10^{21}$ | 1                      | $7.78 \times 10^2$     |
| <b>ft lbf</b> | 1.36                   | $1.36 \times 10^7$     | 0.324                  | $8.46 \times 10^{18}$ | $1.29 \times 10^{-3}$  | 1                      |

**Conversion of Units - Power**

|                  | <b>kW (kJ/s)</b>      | <b>erg/s</b>       | <b>hp</b>              | <b>ft lbf/s</b>       |
|------------------|-----------------------|--------------------|------------------------|-----------------------|
| <b>kW (kJ/s)</b> | 1                     | $10^{-10}$         | 1.34                   | $7.38 \times 10^2$    |
| <b>erg/s</b>     | $10^{-10}$            | 1                  | $1.34 \times 10^{-10}$ | $7.38 \times 10^{-8}$ |
| <b>hp</b>        | $7.46 \times 10^{-1}$ | $7.46 \times 10^9$ | 1                      | $15.50 \times 10^2$   |
| <b>ft lbf/s</b>  | $1.36 \times 10^{-3}$ | $1.36 \times 10^7$ | $1.82 \times 10^{-3}$  | 1                     |

## Options for Preferred Currency and Units

| Settings      | Database Options                                                                                                                                                       |                                                                                                                                                                          |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|               | Preferred Currency                                                                                                                                                     | Preferred Unit System                                                                                                                                                    |
| <Automatic>   | The Regional Setting from the operating system for currency is used to view data. This will appear as <Automatic - <i>Regional Currency</i> >, e.g. <Automatic - GBP>. | The Regional setting from the operating system for unit system is used to view data. This will appear as <Automatic - <i>Regional Units</i> > e.g. <Automatic - Metric>. |
| <None>        | Data is displayed using the same currency as it is stored with in the database.                                                                                        | Attribute data is displayed using the same units as the data is stored with in the database.                                                                             |
| Named setting | Named currency is used to display data.                                                                                                                                | Named unit system is used to display data.                                                                                                                               |

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