CES Selector 2019

Tour of features and getting started exercises

ANSYS GRANTA

We welcome feedback on this documentation. Please let us know if anything is unclear, if you spot an error, or if you have an idea for new content, by emailing docs@grantadesign.com.

Document version: CES19-TFGSE.02
Published: March 2019

Table of Contents

1 About these exercises

These exercises provide an overview of the key tools and features in CES Selector, and form a set of tutorials to help you familiarize yourself with the software. You can work through them in order, or pick and choose relevant ones, to learn about and try out different software features.

There are also Quick Start Videos provided online to teach you about CES Selector. The exercises in this booklet can be used independently of the videos, or used alongside them, to test and check your knowledge.

The exercises here are divided into two sections:

- Section 2, Getting started with CES Selector provides an overview of the main selection and charting features in CES Selector, including:
  - Browsing
  - Searching
  - Charting
  - Filtering
  - Comparison tables
  - Find similar
- Section 3, Getting the most out of CES Selector provides an introduction to additional tools and features for advanced selection methods, including:
  - Favorites
  - Eco Audit Tool
  - Synthseizer Tool
  - User-defined records
  - Performance indices

2 Getting started with CES Selector

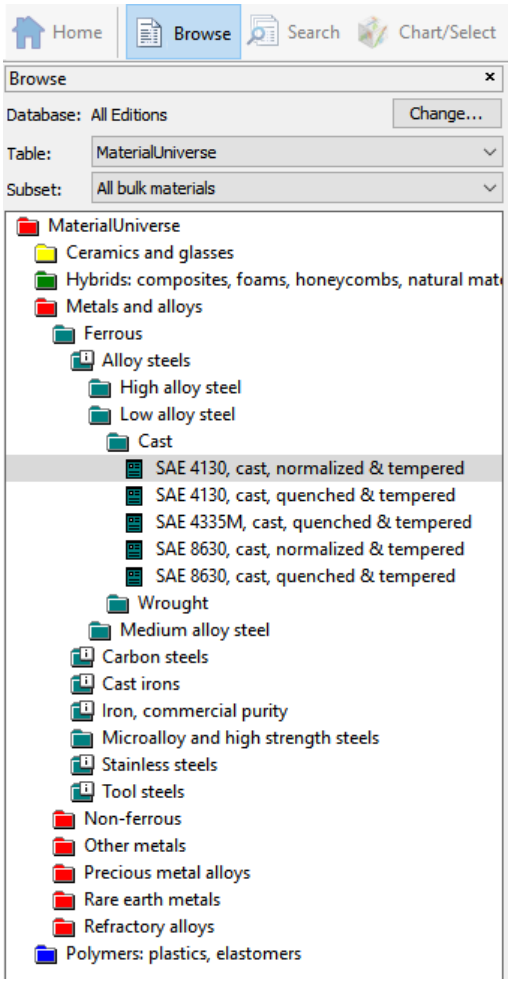
The exercises in this section give an overview of CES Selector and will teach you how to use the core functionality.

In the next section (Getting the most out of CES Selector), you will find exercises that go into further detail, exploring some of the software's more specialized features. There is also comprehensive online help accessible from the software that gives more detailed guidance.

2.1 Main tools in CES Selector

There are three main tools in CES Selector: Browse, Search, and Chart/Select.

BROWSE *– Explore the database*



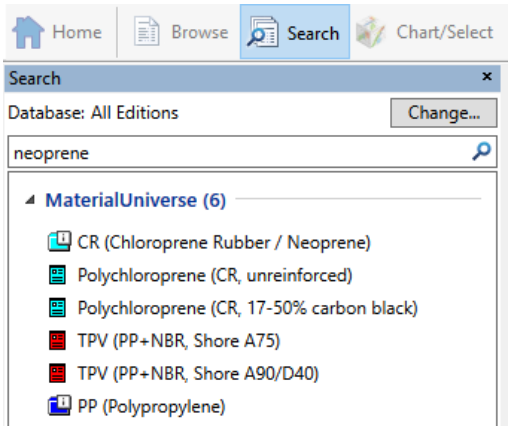
The Browse tree allows you to explore the database, drilling down into the database record hierarchy.

Records in the database are presented in a hierarchical tree structure, table by table. At the top level of the tree are the main 'families' of materials. At the bottom level are specific materials — for example *High density concrete*, *6063 T6 Aluminum*.

In the MaterialUniverse table (shown left), material records are organized into four broad 'families': ceramics and glasses, hybrid materials, metals and alloys, and polymers. Each family is made up of 'classes' (Ferrous, Precious metal alloys, for example) which may contain 'sub-classes' (Alloy steels, Low alloy steel, Cast) consisting of many 'members' (*SAE 4130*, for example).

The categories and hierarchy presented in the Browse tree are specific to each data table: for example, in ProcessUniverse, the records contain process data rather than material data, and are organized by process type: Joining, Shaping, Surface treatment.

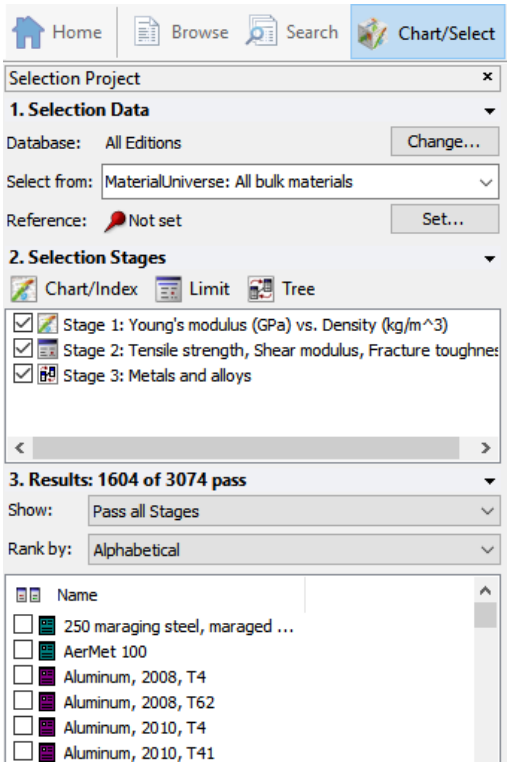
SEARCH *– Find information fast*



You can find materials or processing methods using a simple keyword search. Double-click a record in the Search results list to open its datasheet; the search term will be highlighted wherever it appears.

You can also perform more advanced queries here, for example, using AND, OR and NOT, or searching for phrases ("steel alloy").

SELECT *– Systematic materials selection*



The central hub of CES Selector is a powerful selection engine that identifies records that meet an array of design criteria and enables trade-offs between competing objectives.

A simple 'wizard style' user interface guides you through a systematic rational selection process, making it quick to apply the methods pioneered by Granta founder Professor Mike Ashby.

Graphical tools enable you to make and present decisions. Explore materials space, focus on likely candidates, study trade-offs between cost, engineering performance, and eco behavior.

Structured, repeatable methods ensure you make the right materials choice for your application, e.g., to optimize performance per unit of function, and to minimize cost.

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

2.2 Browsing and Searching

Exercise 1 — Opening a Database

On starting CES Selector, the **Databases** window will appear, showing all installed databases (if more than one database is installed). The following exercises use the MaterialUniverse and ProcessUniverse tables which are supplied with all editions of CES Selector.

When you select a database name in the **Databases** window, the database homepage then appears. Hover over a data module to see the data tables it contains. For example:

Click the **More information on data and usage** link to see a detailed description of a data module.

❖ Select different tables and read about the available data and applications

Click a table in the Database Homepage to select it and see information about it. You can also change the selected table from the graphic on the More information page.

❖ Change to the PROCESSUNIVERSE table

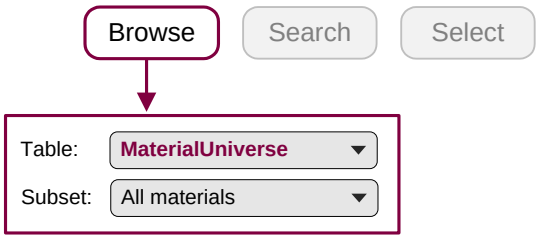
Click **MaterialUniverse>Processes** and notice that the Browse tree updates.

❖ Close the HOMEPAGE

Click the cross at the top of the Home tab. This page can be reopened at any time by clicking **Home** on the main toolbar.

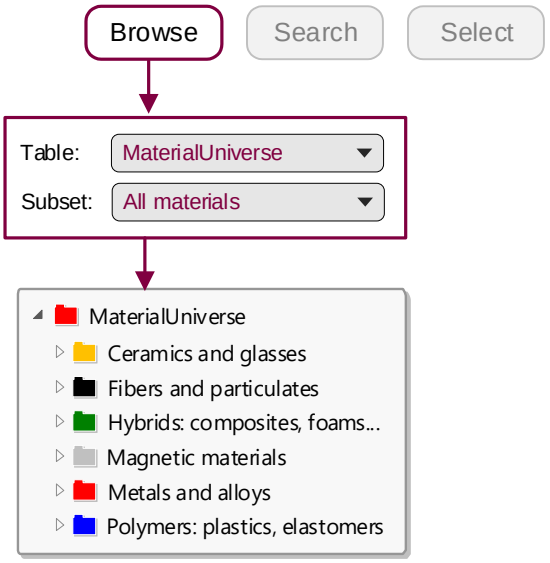
❖ Change to the MATERIALUNIVERSE table

With the Homepage closed, navigate to different tables using the Table list in the Browse window.



Exercise 2 — Browse Materials

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



❖ Browse for a record for STAINLESS STEEL

❖ Browse for 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. They have their own icon: .

❖ Open a specific POLYPROPYLENE record

Double-click the record name in the tree to view the datasheet.

Click ⓘ next to the property name to view design notes, which provide background information on properties, test notes, and selection guidelines.

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

❖ Find PROCESSES that can shape POLYPROPYLENE using the ProcessUniverse link at the bottom of the datasheet

Part of a datasheet for a filled polypropylene material:

Polymers: plastics, elastomers > Plastics > Thermoplastics > PP (Polypropylene) > Barium sulfate filled >

General information

Designation

Polypropylene (65-70% barium sulfate)

Tradenames

NILENE; DENILEN

Typical uses

Furniture; buckets; bowls; general mechanical parts; bottle crates; toys; medical components; washing machine drums; pipes; battery cases; bottles; bottle caps; bumpers; films for packaging; fibers for carpeting and artificial sports surfaces.

Composition overview

Compositional summary

(CH2-CH(CH3))n + 65-70% BaSO4 filler

Material family	Plastic (thermoplastic, semi-crystalline)			
Base material	PP (Polypropylene)			
% filler (by weight)	65	-	70	%
Filler/reinforcement	Mineral			
Filler/reinforcement form	Particulate			
Polymer code	PP-MD70			

Composition detail (polymers and natural materials)

Polymer	30	-	35	%
Mineral (unspecified)	65	-	70	%

Price

Price	* 1.39	-	1.7	USD/kg

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:

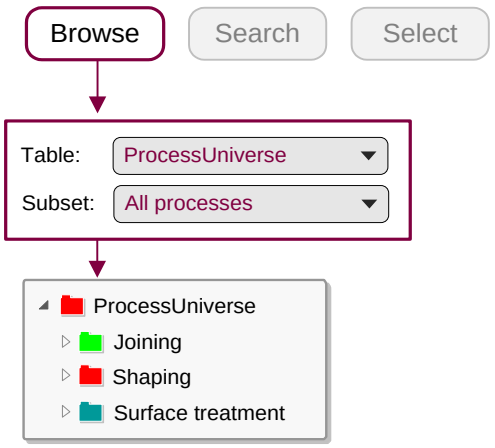
Flexible plastics and elastomers	< 1 GPa
Unfilled plastics	1–4 GPa
Reinforced plastics	5–25 GPa
Ferrous metals	70–250 GPa
Non-ferrous metals	10–310 GPa
Technical ceramics	20–700 GPa
Ceramics and glasses	1–120 GPa

Click to see science note.

For more information on the property and to drill down to the underlying science, follow the hyperlink to the science note.

Exercise 3 — Browse Processes

- Select the Table ***ProcessUniverse*** and the Subset ***All processes***.



- Browse for a record for FRICTION WELDING (METALS)

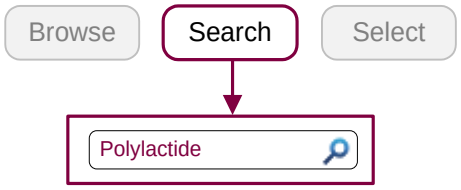
- Browse for a record for TRANSFER MOLDING

- Browse for a record for ION IMPLANTATION

- Find materials that can be DIE CAST, using the link to MaterialUniverse at the bottom of a record for DIE CASTING

Exercise 4 — Searching

❖ Find the material POLYLACTIDE



❖ Find the process VACUUM ASSISTED RTM

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**.

❖ Find the materials for CUTTING TOOLS

Text on the datasheet is also included in the search.

❖ Enter the search term ALUM*

Returns records starting with Alum, such as **Alumina**, **Aluminum**, and **Alumino**.

More advanced searches

The following search operators are available:

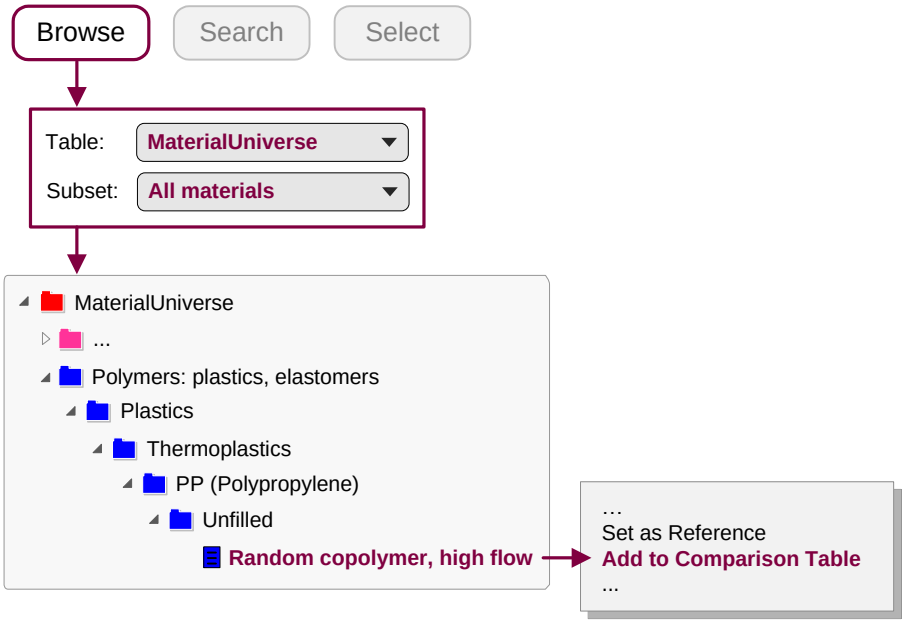
AND	Finds records containing both the search terms, so **steel AND alloy** returns only records containing both the words **steel** and **alloy**
OR	Finds records containing either search term, so **steel OR alloy** returns all records that contain **steel**, **alloy**, or **both**
NOT	Finds records containing the first search term, but not the second, so **steel NOT alloy** returns only records with the word **steel** but without the word **alloy**
Phrase Search	Finds the exact search term, so **"steel alloy"** will return only records containing the exact phrase **steel alloy**
Parentheses	Used to group search terms, so **iron AND (ore OR cast)** will return the records containing **iron** and containing either **ore**, **cast**, or **both**

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

2.3 Comparing Records

The performance of different materials can be compared by creating a Comparison Table.

Exercise 5 — Compare records



❖ Add an unfilled PP (Polypropylene) and an unfilled high-density PE (Polyethylene) record to a COMPARISON TABLE.

Find an example of each in the Browse tree, then right-click and select **Add to Comparison Table**.

❖ Set ***PE-HD*** as the reference record

Hover over the record name in the comparison table and click **Set as Reference** .

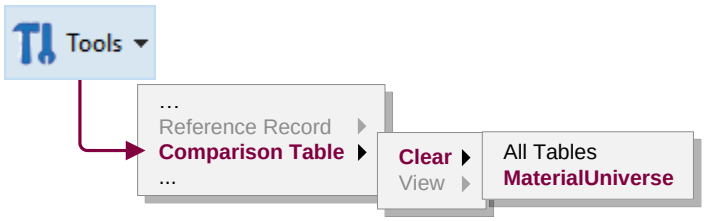
All Data | Project Data | ↔ Ranges | x̄ Averages | #. Values | % Change | Highlight % Change > 10 | Apply

	PE-HD (high molecular weight)	PP (random copolymer, high flow)
Composition overview		
Material family	Plastic (thermoplastic, semi-crystalline)	Plastic (thermoplastic, semi-crystalline)
Base material	PE-HD (Polyethylene, high density)	**PP (Polypropylene)**
Polymer code	PE-HD	PP
Composition detail (polymers and natural materials)		
Polymer (%)	100	100
Price		
Price (GBP/kg)	1.3 - 1.35	1.13 - 1.17
Price per unit volume (GBP/m^3)	1230 - 1290	**1010 - 1070**
Physical properties		
Density (kg/m^3)	947 - 955	895 - 909
Mechanical properties		
Young's modulus (GPa)	0.915 - 0.961	0.824 - 1.02
Specific stiffness (MN.m/kg)	0.962 - 1.01	0.913 - 1.13
Yield strength (elastic limit) (MPa)	19.3 - 26.9	24.1 - 28.4

❖ Change the display to show the differences relative to the reference record as percentages

Click **% Change** in the comparison table toolbar.

❖ Clear the Comparison Table



2.4 Creating property charts

Bar charts and bubble charts are a great way to visualize and communicate materials properties, as well as being a key tool to support systematic materials selection.

Exercise 6 — Create a bar chart

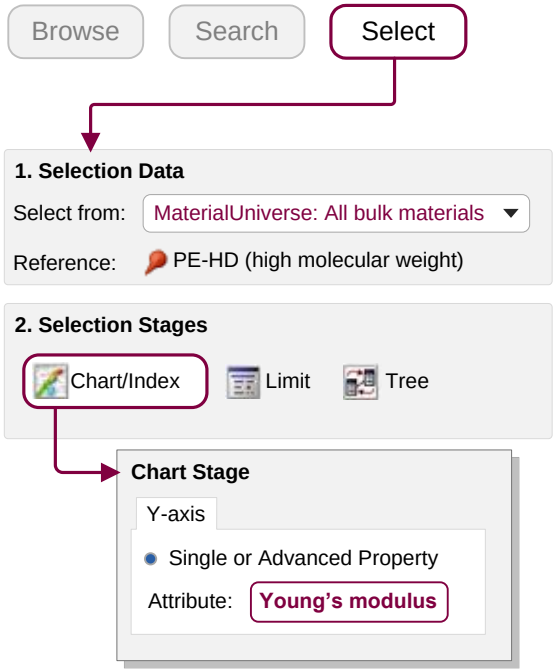
❖ Select MaterialUniverse: All bulk materials

❖ Make a bar chart of YOUNG'S MODULUS (E)

Under Selection Stages, click **Chart/Index**.

Set the y-axis attribute to **Young's modulus**, then click **OK**.

For a bar chart, you do not set an x-axis, so leave x-axis set to <None>.



❖ Explore the chart

Click **Zoom in** and then drag to zoom in on an area of the chart.

Click **Zoom out** to zoom out.

Click **Autoscale** to zoom back to view the whole chart again.

❖ Label records on the chart

Click a record in the chart and then drag to add and position a new data label.

To delete a data label, select it and press DELETE. To delete all labels in the chart, press CTRL+A and then press DELETE.

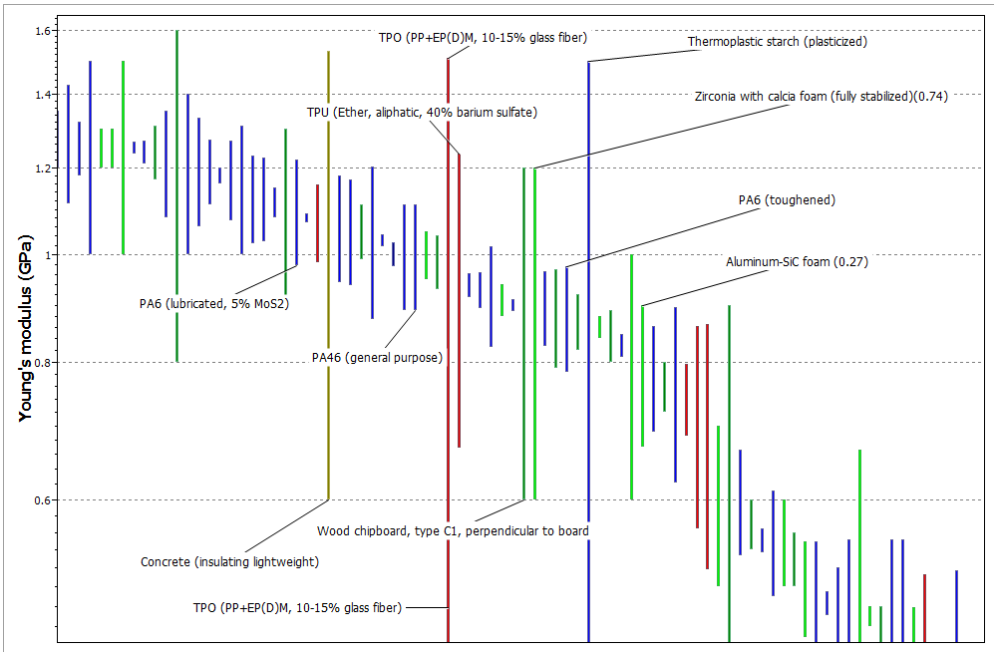


Figure 1 A bar chart of Young's modulus, with data labels

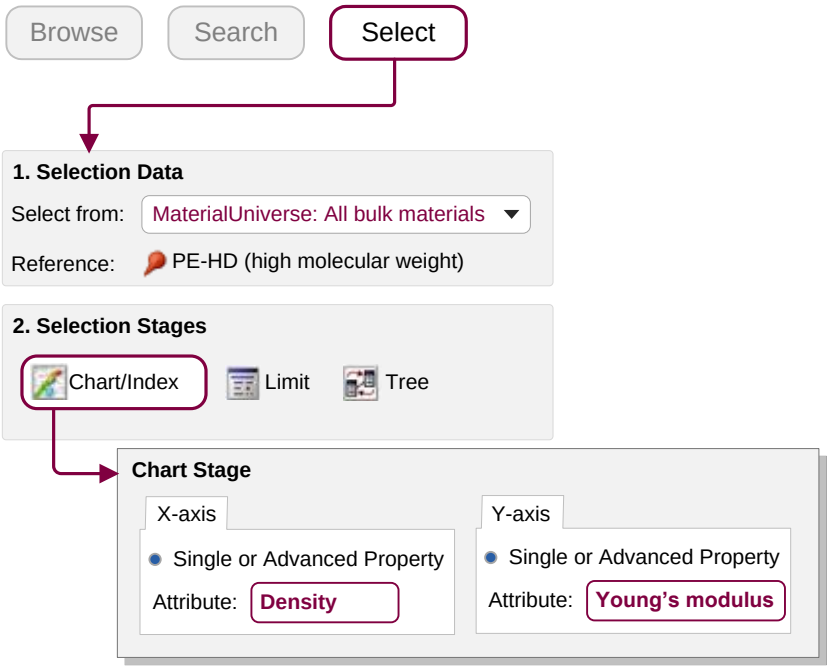
Exercise 7 — Create a bubble chart

❖ Make a bubble chart plotting YOUNG'S MODULUS (E) against DENSITY (ρ)

Under Selection Stages, click **Chart/Index**.

Set the y-axis to **Young's modulus** and set the x-axis to **Density**.

Use the Axis Settings defaults to create a log-log plot.



❖ Show family envelopes

Click  to look at how data for a given family of materials cluster together.

❖ Label records on the chart

Zoom in and label some records (click a record and drag).

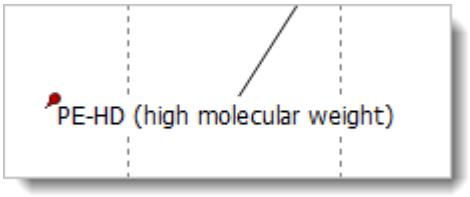
Try adding labels from the Results list: right-click a record in the list, select **Label** on the shortcut menu, and then drag the label to where you want it on the chart.

If the new label isn't visible at the current zoom level, click **Autoscale**  to display the whole chart again.

❖ Locate the Reference Record

Click **Highlight reference record**  on the Chart Stage toolbar; all records except the reference record are grayed out.

Label the reference record. Note that the label includes a special reference record indicator:



❖ Delete this stage

Select the stage in the Selection Stages list and press DELETE.

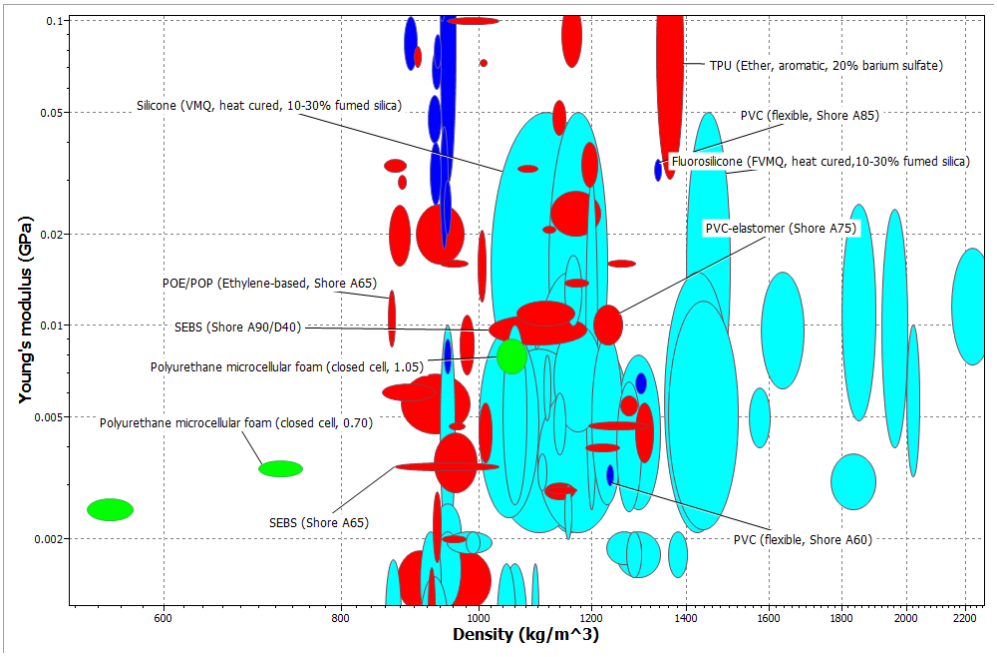
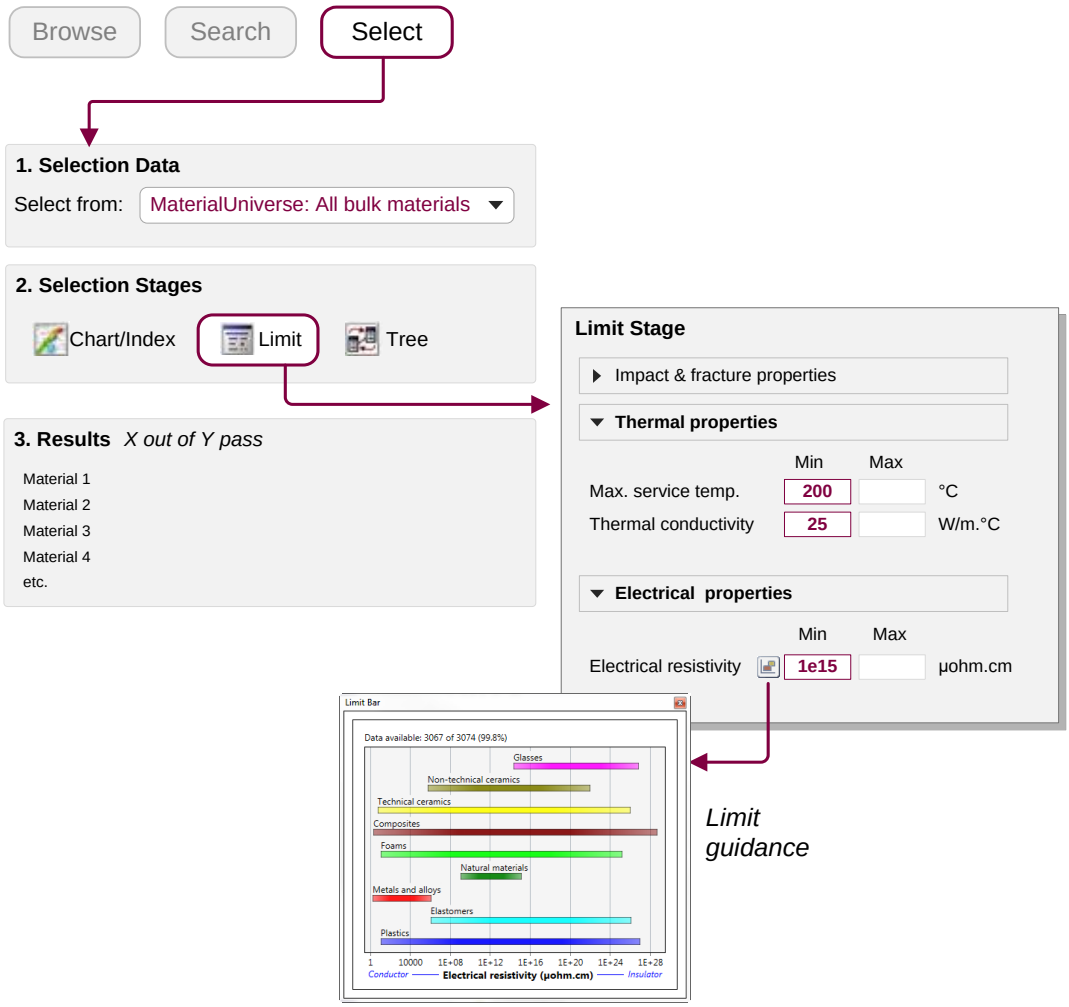


Figure 2 Bubble chart showing Young's modulus (E) plotted against density (ρ)

2.5 Filtering Records

Exercise 8 — Selection Using a Limit Stage



❖ Select materials with specific thermal and electrical properties.

Create a new Limit Stage and enter the following criteria:

MAX. SERVICE TEMPERATURE	> 200 °C
THERMAL CONDUCTIVITY	> 25 W/m.°C
ELECTRICAL RESISTIVITY	> 1e15 µohm.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.

Note: These exercises have been written using the unit settings 'US Dollar (USD)' and 'Metric'. If you use different settings, the selection criteria and figures will differ. To change the settings, click **Settings** on the toolbar, and click the **Units** tab.

❖ Filter the results further to select only materials with non-opaque TRANSPARENCY.

On the Limit Stage under **Optical, aesthetic and acoustic properties**, set the **Transparency** to **Translucent**, **Transparent**, and **Optical quality**.

Click **Apply**.

Example results: Alumina (translucent) and Diamond.

❖ Delete this stage.

Exercise 9 — Using the Engineering Solver

Design requirements are often specified in terms of geometry, loading, and maximum deflections. The Engineering Solver tool converts these engineering requirements into material properties, which can then be applied in Limit stages to screen for suitable materials.

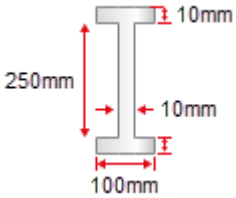
❖ Open the Engineering Solver tool.

Click **Solver** on the main toolbar.

❖ Select the situation **Beam in Bending**.

This model estimates the minimum strength and stiffness values required for a beam with the specified geometry and load conditions.

❖ Set up the geometry for an I-beam with the following cross-section dimensions.



Use the Cross-section list to select **I-section**. Enter the following dimensions and use the lists at the end of each line to select the correct units: Breadth (b) 100mm; Depth (d) 250mm; Thickness (t) 10mm; Web thickness (tw) 10mm; Length (l) 5m.

❖ Set up the design parameters for a cantilever with an end load of 5kN.

Load conditions = Cantilever End load

Load = 5kN
Safety factor = 1.5

Maximum deflection = 50mm
The results will automatically populate. You should see that the minimum required Young's Modulus is 133GPa and the minimum Yield Strength is 108MPa. You can change the units for the results using the adjacent lists.

Keep the Engineering Solver window open.

❖ Select materials based on the results from the Solver tool.

Create a new Limit stage with All bulk materials, using the Young's modulus and Yield strength results from the Engineering Solver.

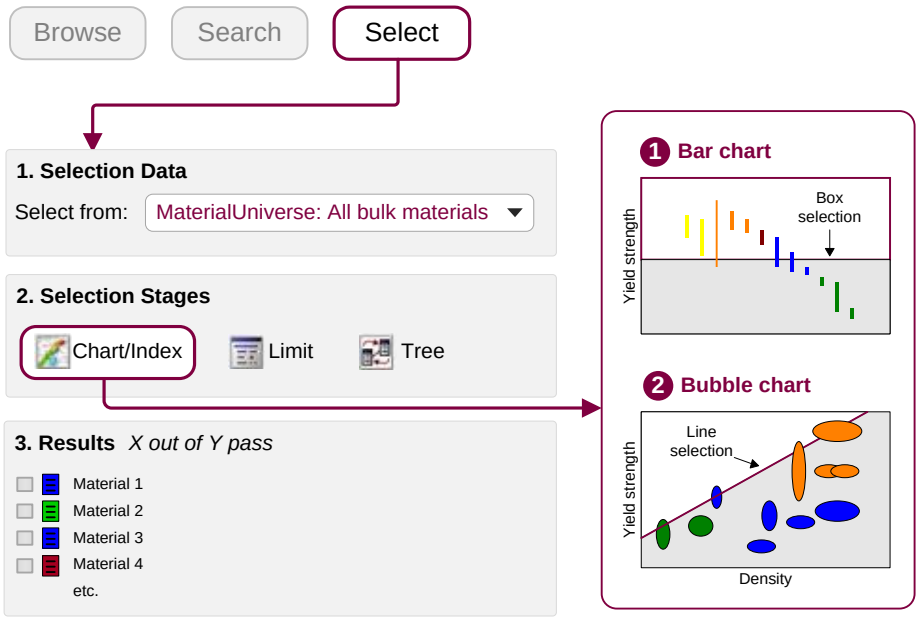
Enter the minimum **Young's modulus** and **Yield strength (elastic limit)** values.

Make sure that the results units in the Engineering Solver and Limit Stage match: change the results units in the Engineering Solver if they do not match those in the Limit Stage.

Example results: Alumimum, Alumina, Berylium, Bronze, Carbon Steel... as you can see, a large number of results are returned. It would then be standard to perform further selection stages to narrow down the list of potential materials (e.g. setting a maximum price).

Exercise 10 — Selection Using a Chart Stage

When plotted on a Chart Stage, records can also be filtered using the **Index line** and **Box selection** tools. This provides a more qualitative approach to filtering.

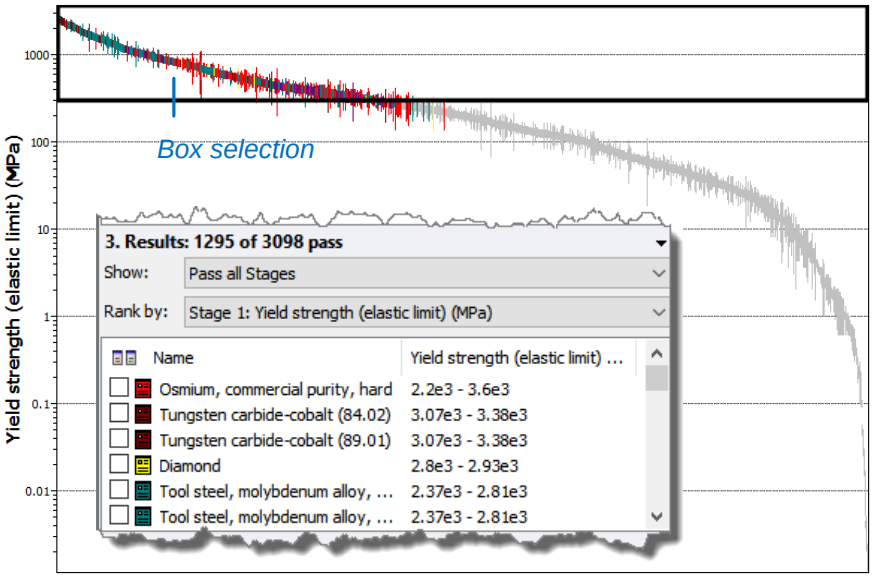


❖ Make a bar chart of YIELD STRENGTH (σ_y)

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

❖ Use a box selection to identify materials with high values of YIELD STRENGTH

Click **Box selection**  , then drag to define the selection box.



❖ Add DENSITY (ρ) to the other chart axis

Click **Chart Settings**  , and on the x-axis tab, select **Density** as the axis attribute.

❖ Use an INDEX LINE to identify materials with high values of the specific strength σ_y / ρ

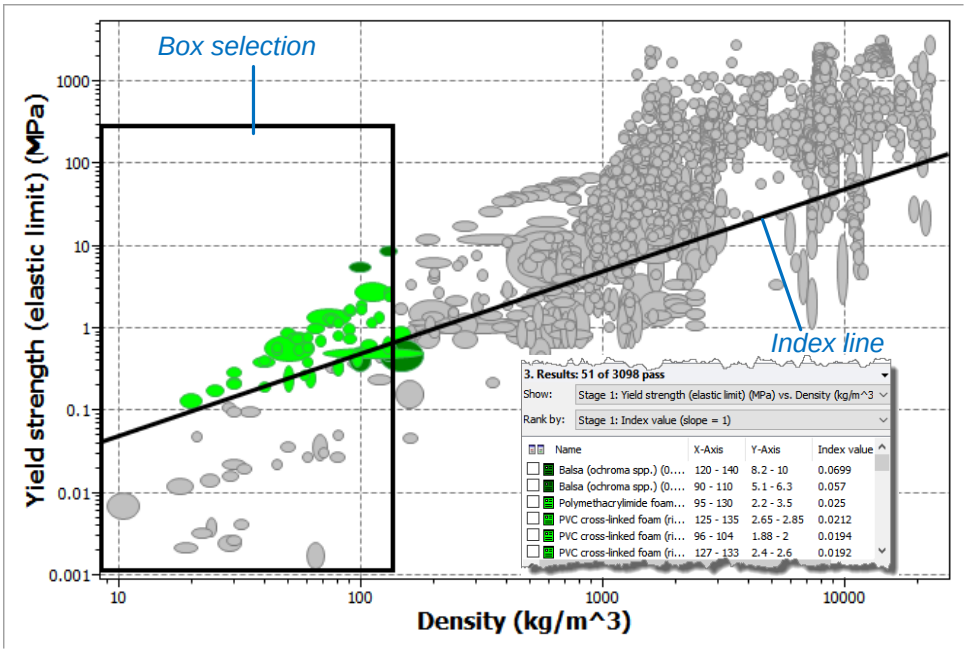
Click **Index line**  .

By default, the slope of the line is 1 and the objective is **Maximize the index.** This will result in selection of materials above the line, for high values of σ_y / ρ.

Click **OK** and then click the chart to position the line through a particular point.

Drag the line upwards to refine the selection to fewer materials.

❖ Add a Box selection to the chart to identify materials with low DENSITY that maximize the index.



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

Show: Stage 1: Yield strength v. Density

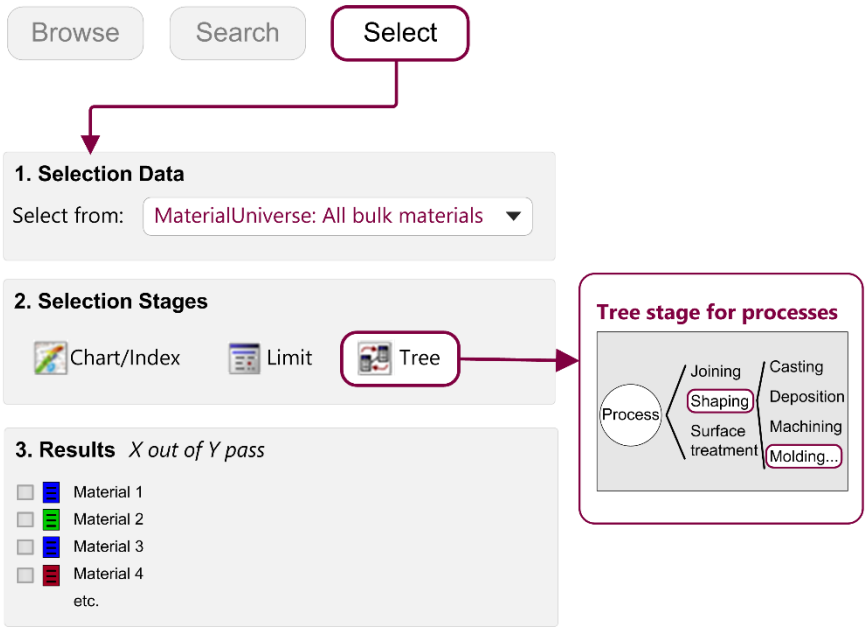
Rank by: Stage 1: Index value.

Example results: Balsa, Polymethacrylimide foam, PVC.

❖ Delete all stages

Exercise 11 — Selection Using a Tree Stage

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



❖ Find materials that can be MOLDED

Under Selection Stages, click **Tree**. In the Tree Stage window, select ProcessUniverse, navigate to Molding. Select Molding, click **Insert**, and then click **OK**.

❖ Click **Show** to see a list of the materials in MaterialUniverse to which this process is linked.

❖ Delete this stage.

❖ Find processes to join STEELS

In the Selection Project pane, under Selection Data, select *ProcessUniverse: Joining processes*.

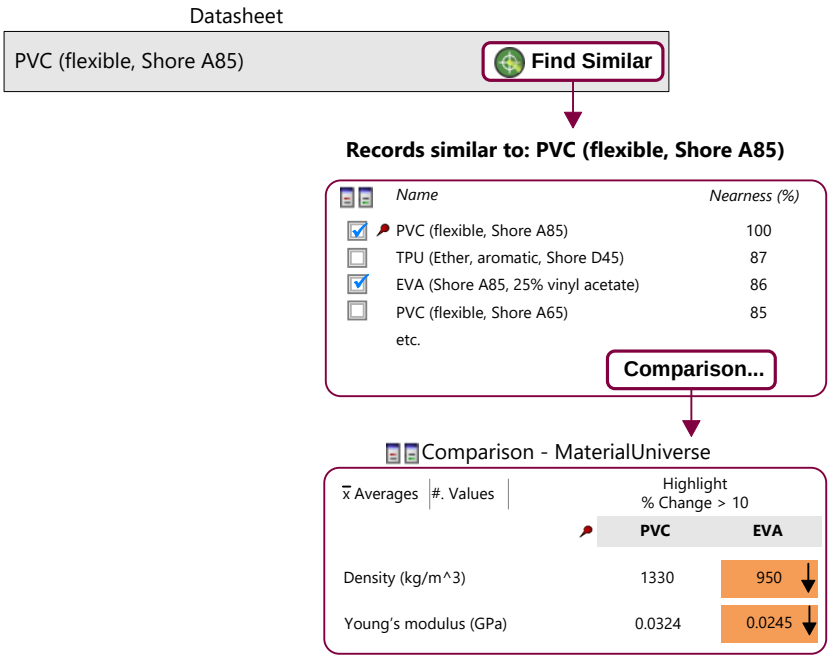
Under Selection Stages, click **Tree**. Select *MaterialUniverse*, expand *Metals and alloys*, select *Ferrous*, and then click **Insert** followed by **OK**.

❖ Delete this stage.

2.6 Find Similar

Materials in the database can be ranked based on their similarity, or nearness, to a specified material. This is useful for finding replacement or equivalent materials. The way in which nearness is calculated can be tailored to account for specific design requirements behind the initial material choice.

Exercise 12 — Find Similar and Nearness Settings



❖ Open the datasheet for PVC (flexible, Shore A85)

❖ Find similar materials

Click **Find Similar** and confirm changing the reference record, if prompted.

Available materials are ranked by their similarity to the reference material. In this instance, calculations are based on the default nearness criteria for this table.

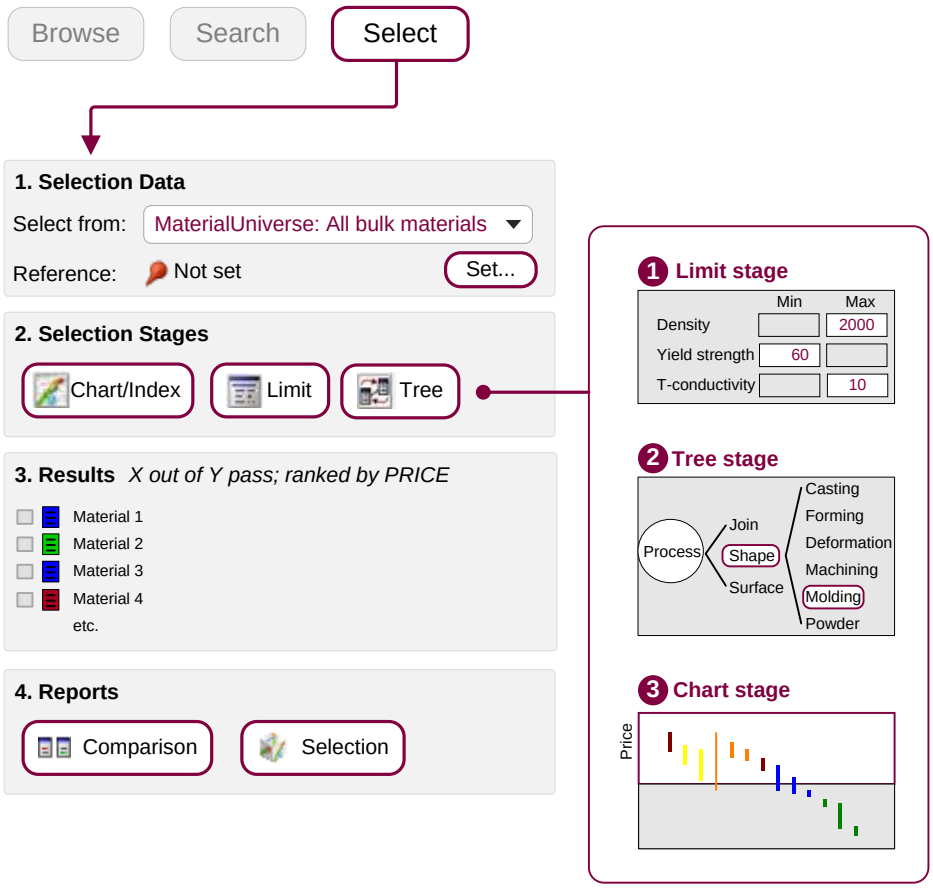
❖ Compare PVC with one of the near materials

Select EVA (Shore A85, 25% vinyl acetate) and click **Comparison**.

A comparison table is generated, showing the selected result and the reference record. Significant differences in the attribute values are highlighted.

2.7 Putting it all together

Exercise 13 — Combining Filtering and Charting Tools



❖ Choose the data source and set a reference record.

Select from: MaterialUniverse: All bulk materials

Reference: POM (homopolymer)

❖ Select materials with specific physical, mechanical, and thermal properties.

Add a Limit Stage with the following criteria:

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

❖ Filter the results to find those that can be THERMOFORMED

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

❖ Rank the results by PRICE

Add a Chart Stage with a bar chart of Price. On the Chart Stage, all materials that fail one or more stages are grayed out. The Results window lists the materials that pass all stages.

In the **Rank by** list, select *Stage 3: Price*.

❖ Compare the three cheapest materials

Select the top three records in the **Results** list and click the **Comparison** button below the list to add them to a Comparison Table with the reference record.

❖ Create a Selection Report

Below the Results list, click **Selection**.

A selection report is created, containing a summary of the selection project on the first page, details of each selection stage on the following pages, and the comparison table on the final page.

Exercise 14 — Finding Supporting Information

The following exercise requires an Internet connection.

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

❖ Search the web to find more information on PET

Open a PET datasheet, and then click **Tools>Search Web**.

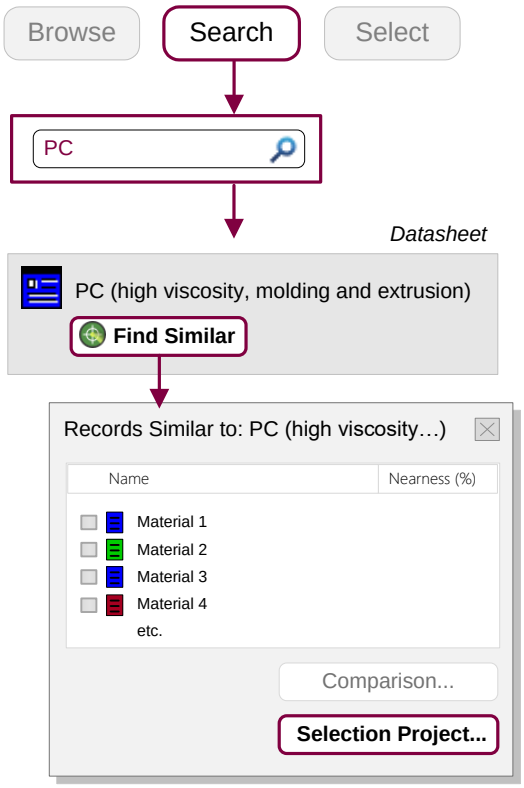
Exercise 15 — Search and Find Similar

❖ Search for a material and open its datasheet

Use **Search** to find and display ***PC (high viscosity, molding and extrusion)***.

❖ Find records similar to the selected record

Click **Find Similar** . Use the default weightings to calculate nearness; do not open the Nearness Settings window.

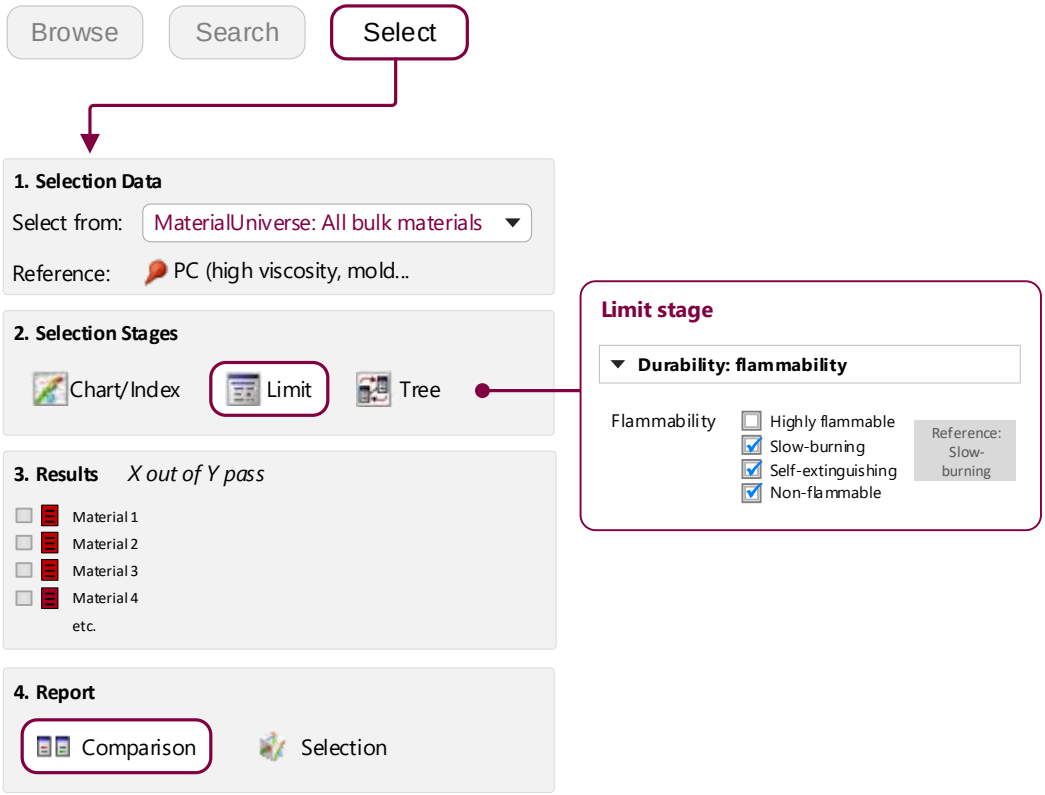


❖ Apply additional design constraints

Click **Selection Project** to create a selection project and rank the results by nearness to the reference record.

Add a Limit Stage and select materials with equal or poorer flammability than the reference.

	Slow-burning
FLAMMABILITY	Self-extinguishing
	Non-flammable



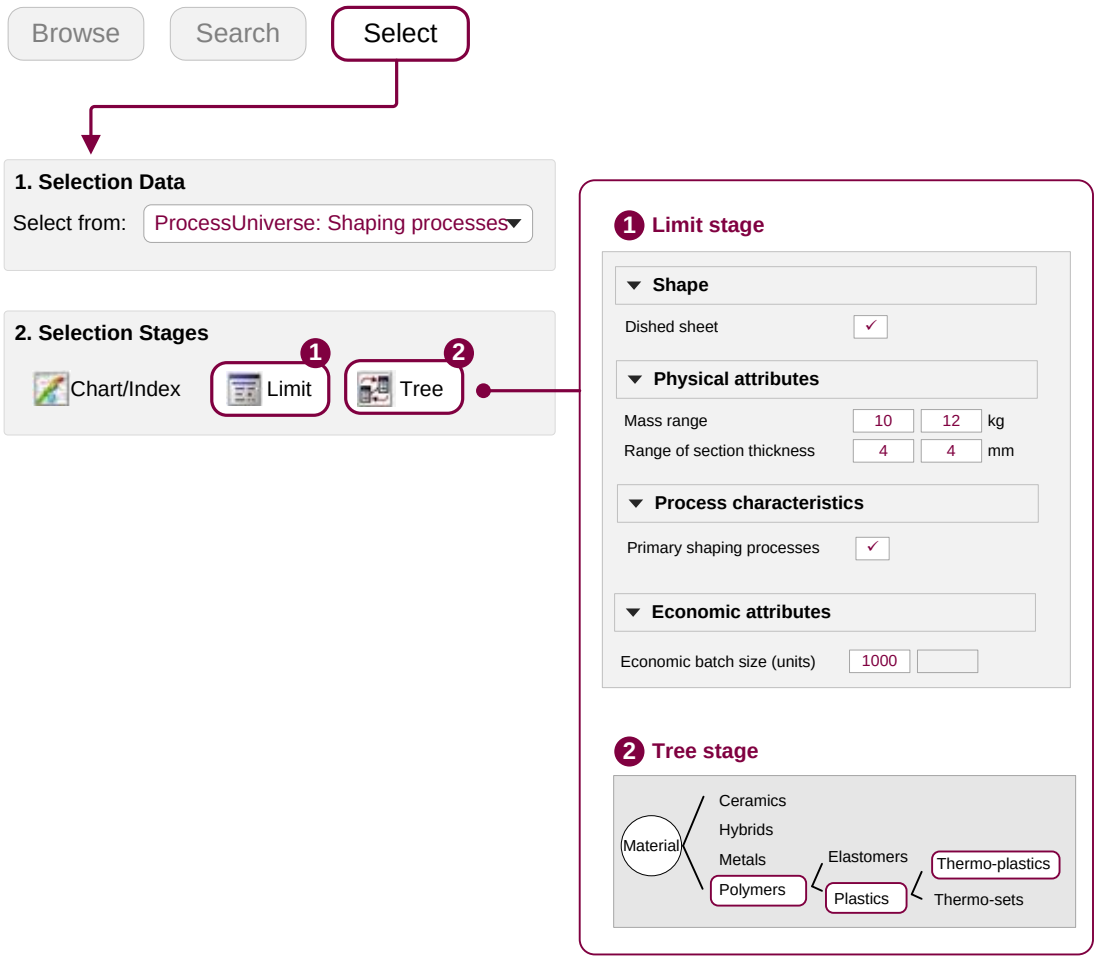
❖ Compare the selection results

In the Results list, select ***PBT (general purpose)*** and ***PPE+PS alloy (15% glass fiber)***, then, under Report, click **Comparison**.

❖ Use the comparison table to check for other significant differences in performance, for example, ELONGATION.

2.8 Process Selection

Exercise 16 — Selecting Processes



❖ Choose the Selection Data.

Select from: ProcessUniverse: Shaping processes.

❖ Find PRIMARY SHAPING PROCESSES to make a component with specific shape, physical, and economic properties.

Add a Limit Stage with five criteria:

SHAPE	Dished sheet
MASS RANGE	10 - 12 kg
SECTION THICKNESS	4 mm
PRIMARY SHAPING PROCESS	Yes
ECONOMIC BATCH SIZE	> 1000

❖ Filter the results to only include THERMOPLASTIC materials

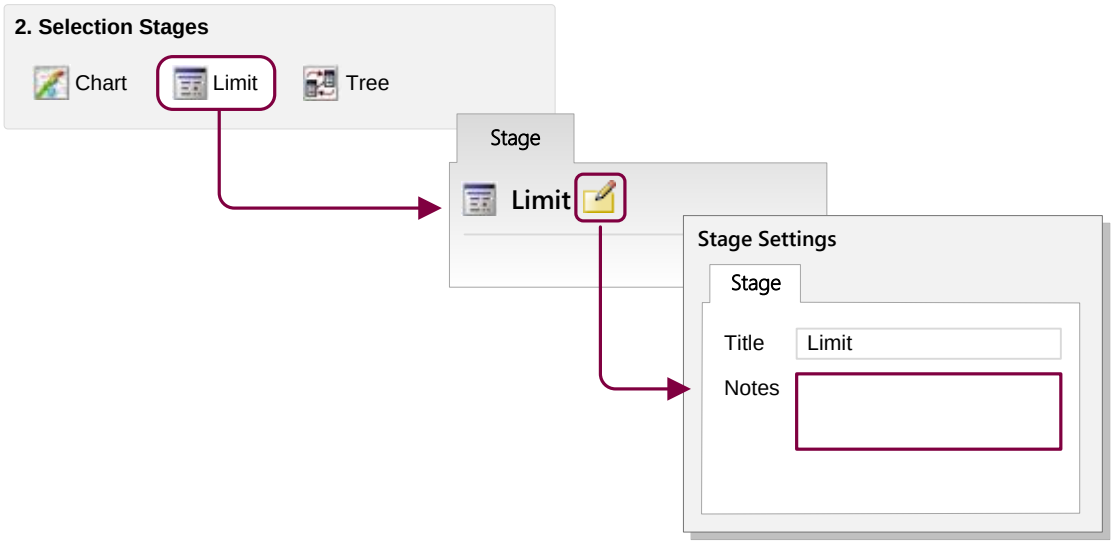
Add a Tree Stage and select MaterialUniverse - Polymers - Plastics - Thermoplastics.

Example results: Compression molding, Rotational molding, Thermoplastic composite molding.

2.9 Saving, Copying, and Report Writing

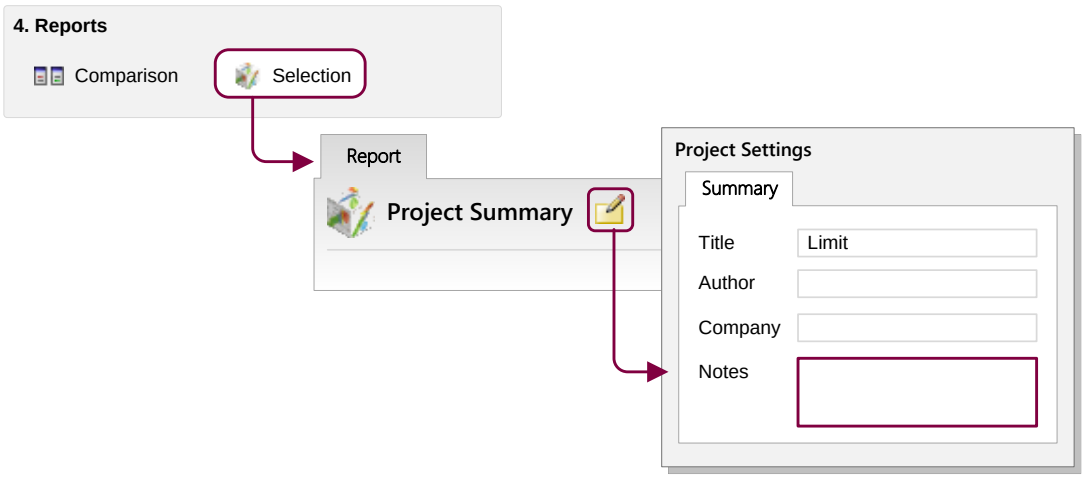
Exercise 17 — Adding Comments and Saving a Project

You can add comments to a selection project as a reminder of why you have applied certain constraints and objectives. Comments are displayed in the selection report, and are saved in the project file.



Comments can be added to all selection stages in a project.

- Click **Notes** in the stage window heading, then enter some comments.
- You can also add comments to the selection report summary and include, for example, information on which material was finally selected and the reasons why, to provide full traceability of the material selection.



❖ Save the project

On the **File** menu, click **Save Project**. Give the project a filename and directory location; the project will be saved with the file extension *.ces*.

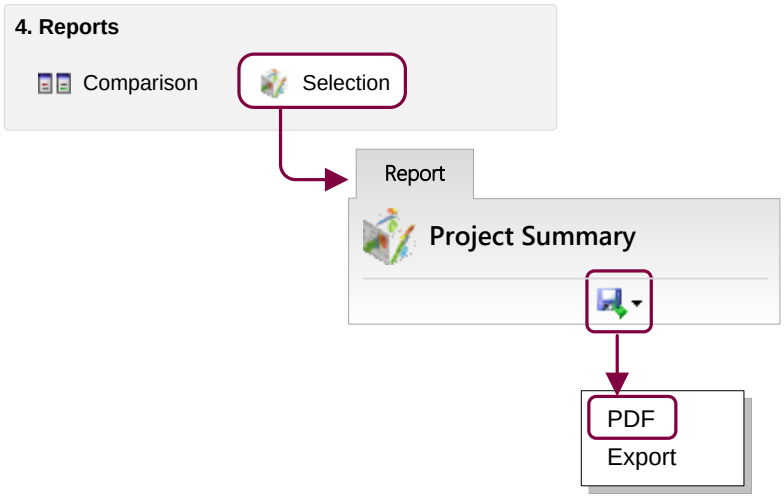
Exercise 18 — Exporting and Copying

Reports can be exported as a PDF or as a Microsoft® Word document.

❖ Generate a Selection Report

❖ Export the report as a PDF

Click **Export** and select **PDF**.



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

Charts, records, and results lists can be copied and pasted into a document in another application such as Microsoft Word, Microsoft Excel, Microsoft Powerpoint, or Notepad.

❖ Copy a chart into a document.

To copy a chart to the clipboard: in the chart window, right-click the chart and select **Copy** on the shortcut menu, or press CTRL+C.

You can then paste the chart image from your clipboard into the document.

❖ Copy a datasheet into a document.

To copy a datasheet to the clipboard: display the datasheet and then right-click the datasheet and select **Copy** on the shortcut menu, or press CTRL+C.

You can then paste the data from your clipboard into the document.

❖ Copy results into a document.

To copy results to the clipboard, use SHIFT+click or CTRL+click to highlight the records you want, then right-click and select **Copy** on the shortcut menu, or press CTRL+C.

To select all results in the list, right-click and select **Select All** on the shortcut menu, or press CTRL+A.

You can then paste the results from your clipboard into the document.

❖ Edit the document you have created.

3 Getting the most out of CES Selector

The following exercises introduce some additional tools and features designed for advanced selection methods.

- 3.1 Custom Selection
- 3.2 Performance Indices
- 3.3 Functional Data
- 3.4 Find Similar with Additional Criteria
- 3.5 Eco Audit
- 3.6 Synthesizer Tool

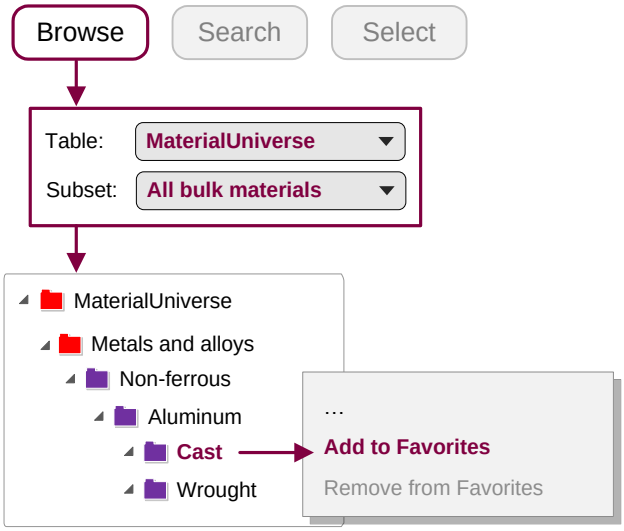
3.1 Custom Selection

Exercise 19 — Favorites

The Favorites feature enables you to highlight your favorite records e.g. your company's preferred materials.

❖ Browse to the CAST ALUMINUM folder and add the folder as a favorite

Right-click the folder name and select **Add to Favorites**. This will add the folder and all records within that folder to favorites. On the browse tree and data labels, any favorite record will be marked with a star.



❖ Add the TYPE 66 PA folder as a favorite as well

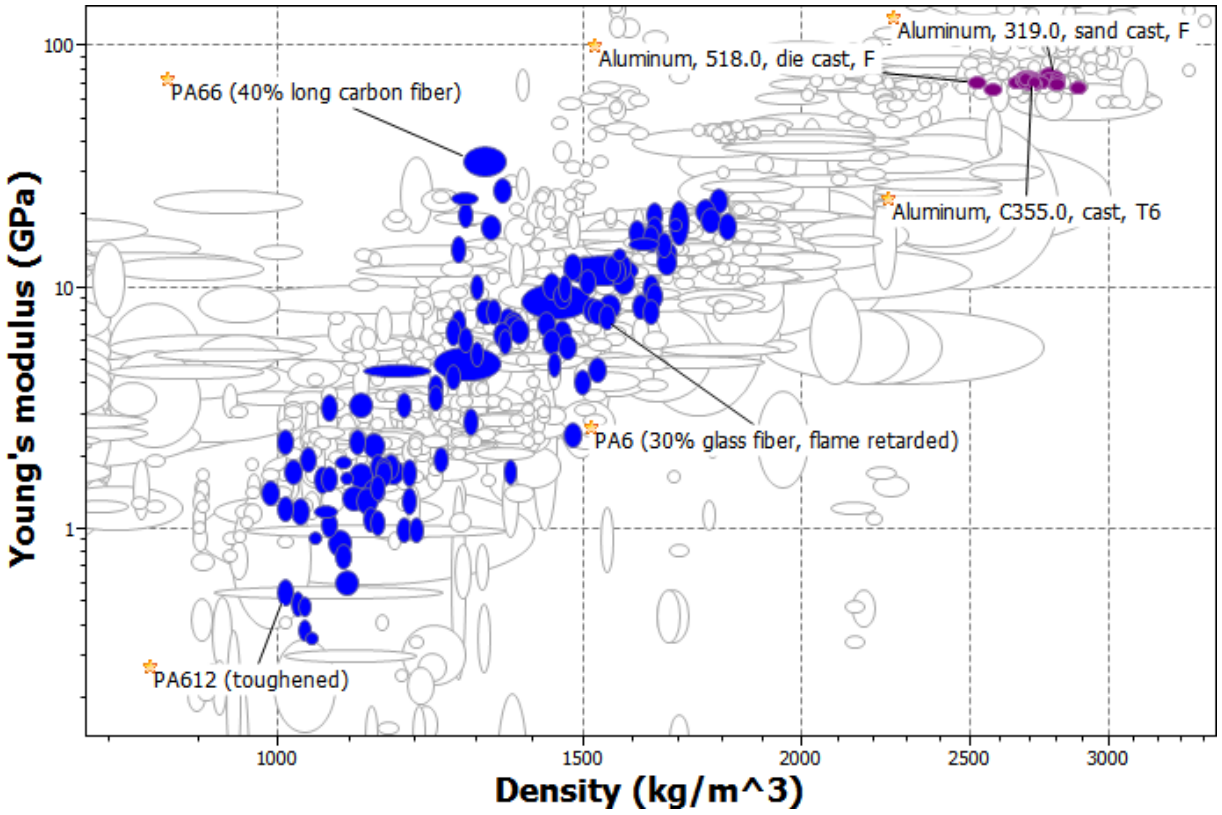
Expand Polymers - Plastics - Thermoplastics - PA (Polyamide/Nylon)

❖ Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY (ρ)

Select MaterialUniverse: All bulk materials and create a bubble chart as in Exercise 7.

❖ View your favorites on the chart.

Click **Highlight favorite records** ; all the materials that are not favorites are grayed out. Add labels to some of your favorites.



❖ Clear your Favorites

On the **Tools** menu, click **Favorites>Clear**.

❖ Retain this stage for the next exercise

Exercise 20 — Adding user-defined records

New materials are continuously being developed and introduced onto the market. These materials can be added and compared with other materials in the database using the User Defined Record feature.

A user-defined record appears on the Browse tree under **My records**.

User-defined records are saved in the selection project file, not the database.

❖ Add a Limit selection stage with the following constraint:

THERMAL EXPANSION COEFFICIENT < 100 µstrain/°C

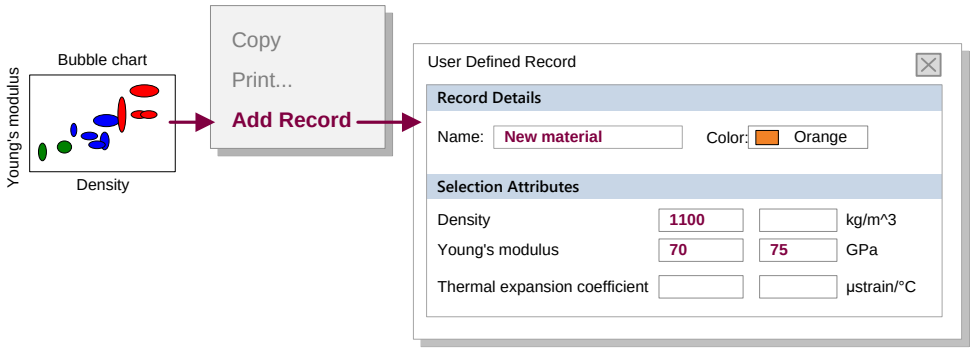
❖ Add a user-defined record

Right-click in the bubble chart and select **Add Record**.

❖ Set the following values for the new record:

NAME	New material
DENSITY	Min. 1100 kg/m^3
YOUNG'S MODULUS	70 - 75 GPa

Click **OK** when finished. The new record will be shown on the Chart Stage with the default color as orange.



❖ View the new record on the chart

On the Stage toolbar, click **Highlight user defined records** ; all the materials that are not user-defined are grayed out.

When a record is added from a chart, only the selection attributes are shown for data entry. User-defined records do not fail stages when no value has been entered for a specified constraint (such as thermal expansion in this example).

To edit or delete a user-defined record: right-click the record in the Browse tree and select the option on the shortcut menu.

❖ Delete the Limit Stage, but keep the initial Chart Stage, as this will be needed for the next exercise

❖ Save the project

Exercise 21 — Selection with a Custom Subset

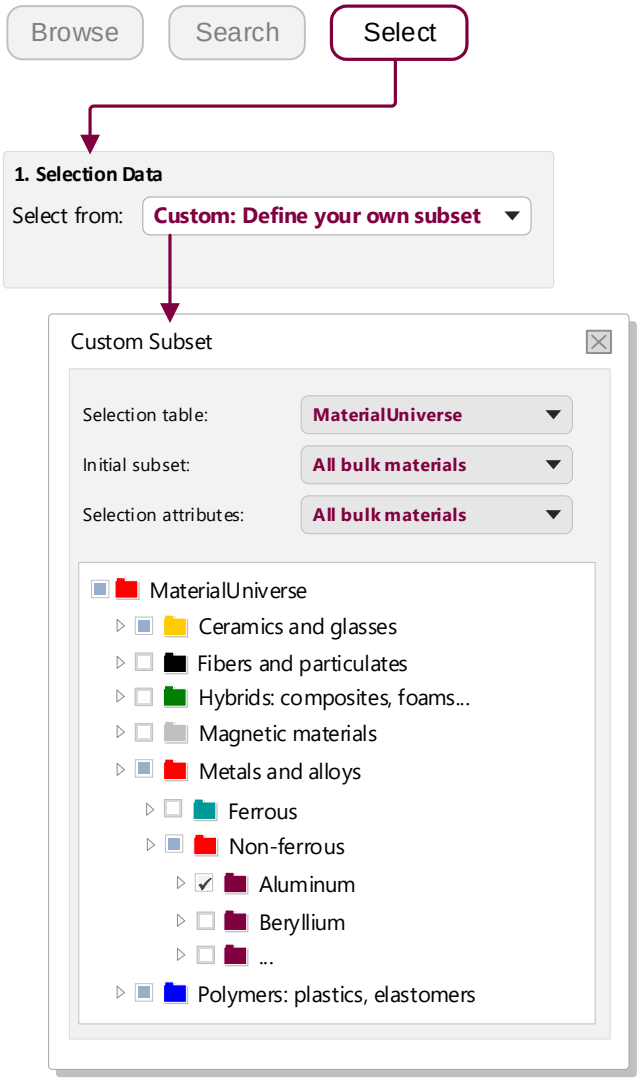
The CES Selector databases are supplied with a range of standard subsets (e.g. *All bulk materials*, *Metals*, *Magnetic materials*) which enable users to restrict their material selection to certain material groups within the database. The custom subset feature enables you to define your own subsets.

❖ Define a custom subset

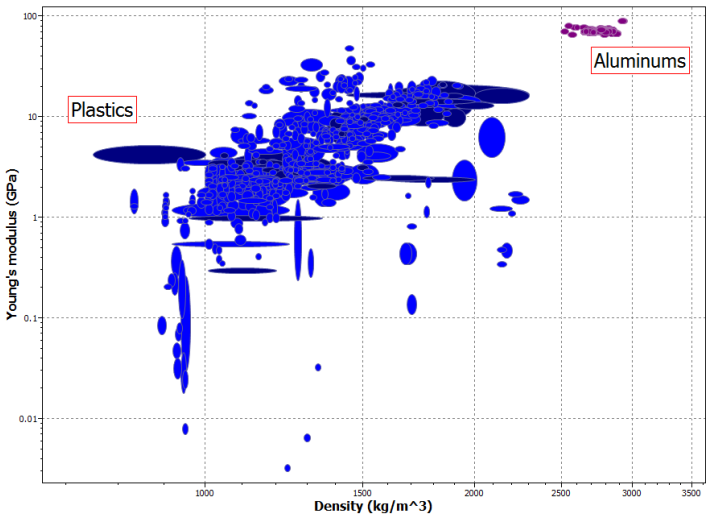
In the **Select from** list, choose **Custom: Define your own subset**.

Select ALUMINUM and PLASTICS and see that the bubble chart updates.

In the Custom Subset dialog, use the check boxes to include or exclude records and folders.

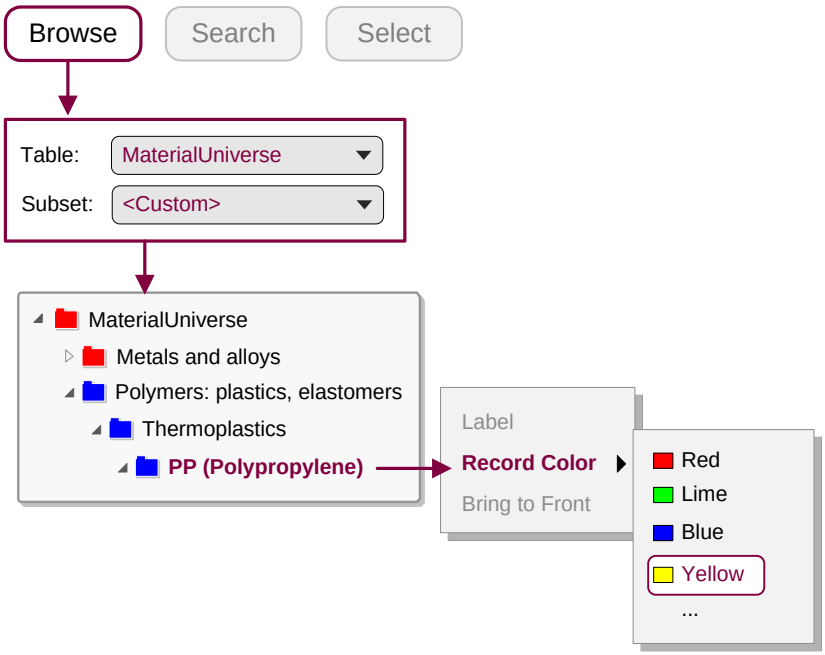


Note: The Selection attributes setting defines what properties will be available in chart and limit selection stages.



Exercise 22 — Record Coloring

The CES Selector databases use a standardized color scheme for displaying records (e.g. blue for plastics). You can change the default colors to highlight particular records.



❖ Browse to the POLYPROPYLENE folder, right-click the folder name and change the record color to Yellow

Note: Record colors can also be changed by right-clicking on a record in a chart stage or the selection results list.

❖ Check that the record color on the bubble chart has updated

❖ Delete this stage

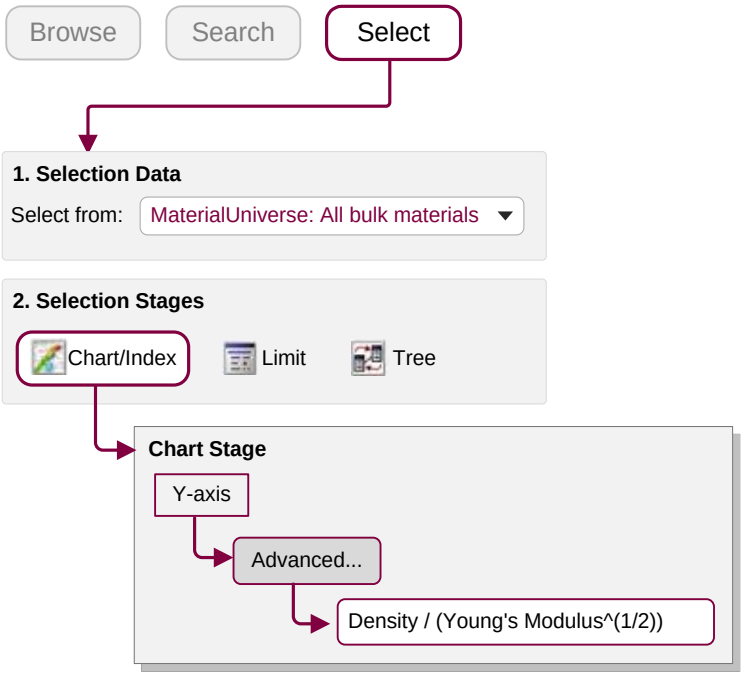
Exercise 23 — Plotting a combined property

Many engineering applications require combined properties to be optimized. For example, specific stiffness (Young's modulus / density) in aerospace, and thermal diffusivity (thermal conductivity / (density * specific heat)) in thermal applications. You can plot these types of properties using the Advanced property feature.

❖ Make a BAR CHART of the combined property DENSITY / (YOUNG'S MODULUS ^ (1/2))

In the Chart Stage Wizard, under the Y-Axis tab, click **Advanced**. In the Set Axis dialog, select an attribute and click **Insert** to build the expression.

Leave the x-axis with no attribute set, to generate a bar chart.



❖ Delete this stage.

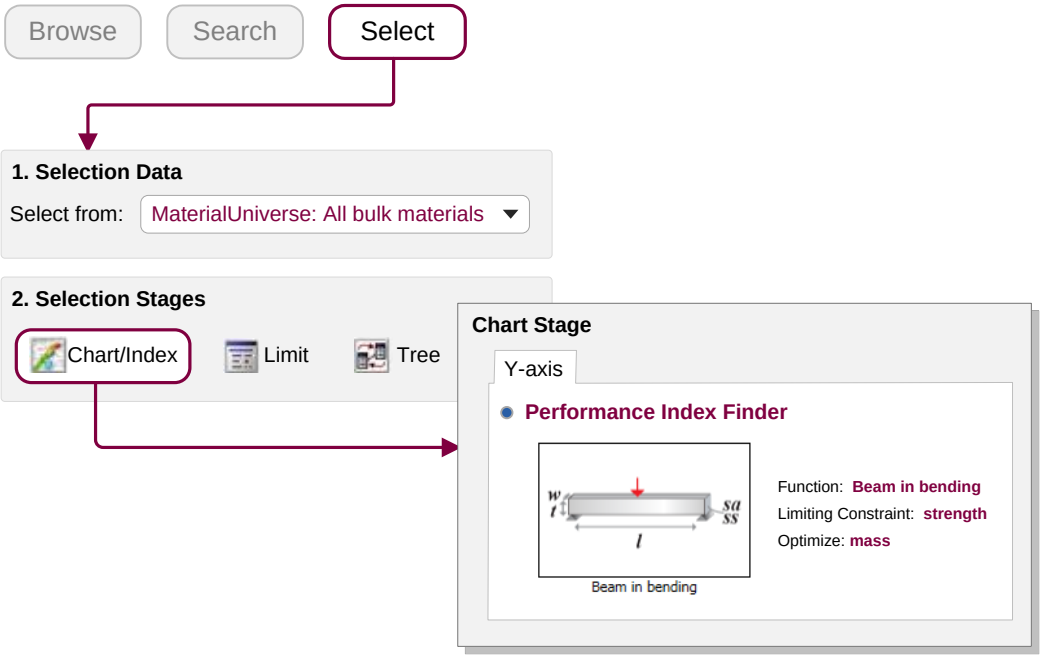
3.2 Performance Indices

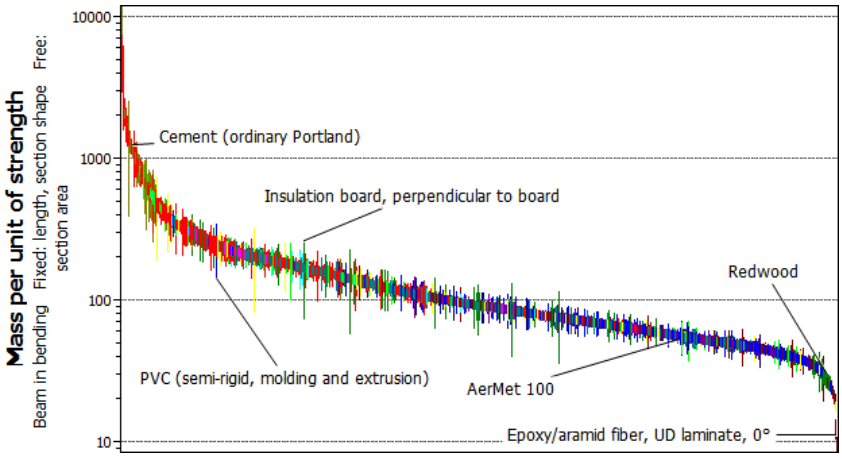
One of the main components of the rational material selection technique is the use of performance indices. These are combined properties (e.g. Young's modulus / density) that allow the function of a design to be optimized for a particular application. The performance index finder enables users to quickly identify (and plot) the performance indices that are applicable to their design.

Exercise 24 — Performance Index Finder

❖ Make a BAR CHART of the performance index for minimizing the mass of a strength-limited beam, loaded in bending

In the Chart Stage Wizard, under the Y-Axis tab, select Performance Index Finder. Select the **Beam in bending** function. Set section area as a free variable, strength as the limiting constraint, and optimize for mass.



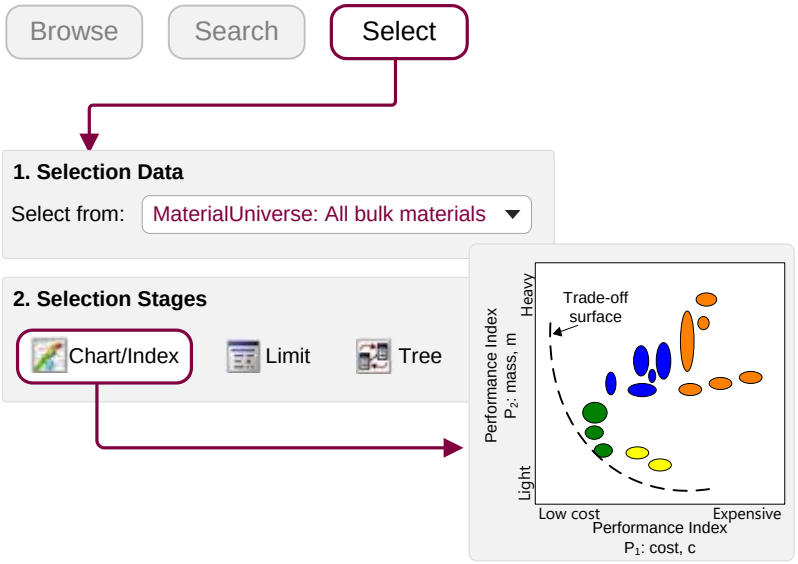


Exercise 25 — Selection with a Trade-off Plot

Many designs require a compromise to be made between competing objectives, for example, maximize performance and minimize cost. The influence of this 'trade-off' on material choice can be studied by generating a trade-off plot, where candidate materials lie along a hypothetical curve or trade-off surface. You can identify optimal materials for a particular application by making a judgment on the relative importance of the two objectives (e.g. in aerospace, high performance is more important than low cost).

❖ Make a BUBBLE CHART of the performance index BEAM IN BENDING, limited by STRENGTH

Set the y-axis to optimize mass and the x-axis to optimize cost.



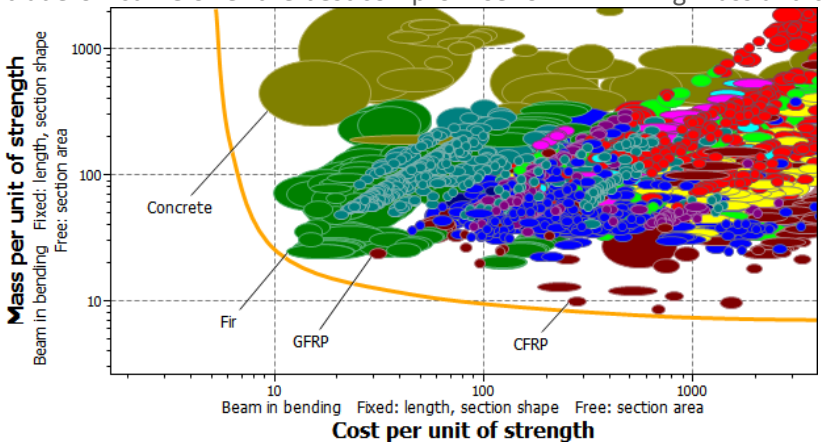
❖ Create a trade-off curve by adding a curve annotation to the chart

On the chart stage toolbar, click **Curve**.

Click the chart at the points you want the curve to pass through.

Press **Enter** to finish editing the curve.

The curve is a guide to the eye, and does not perform selection. The materials closest to the trade-off curve offer the best compromise for minimizing mass and cost.



3.3 Functional Data

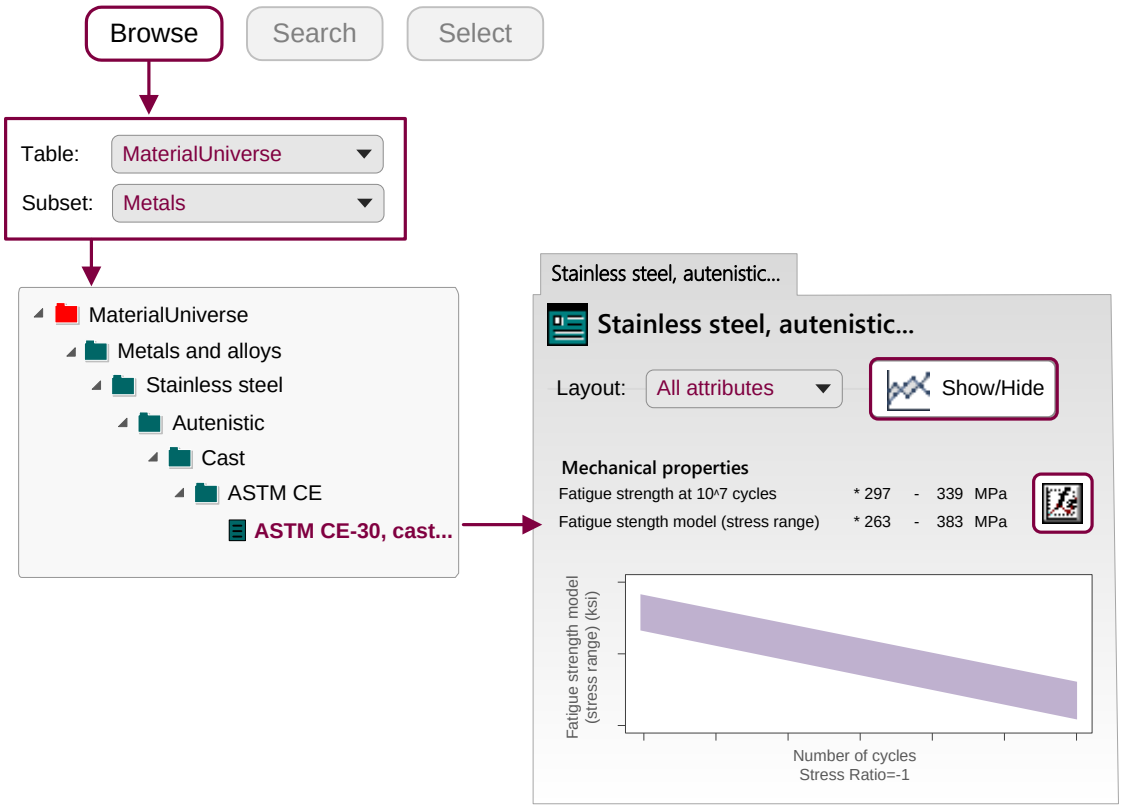
Some properties within the databases are stored as functional data, meaning that data is available for a number of different conditions. This allows users to readily incorporate the conditions of their application into their selection project. For example, using the “Fatigue strength model”, you can specify both the stress ratio and number of cycles for the fatigue strength.

Exercise 26 — Viewing Functional Data

❖ Open the datasheet for a STAINLESS STEEL record. If the functional data graphs are not already visible, set them to be shown

Click **Show/Hide** to toggle functional data graphs on the datasheet.

Use the graph buttons to open a graph in a new window and view the equation or data points.



Exercise 27 — Setting Parameters for Functional Data

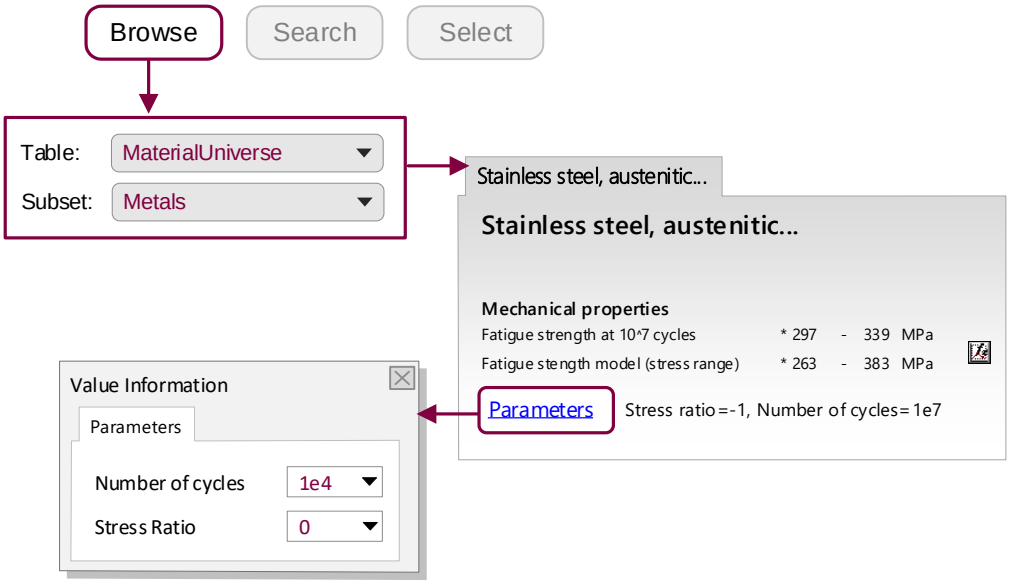
The parameter values for functional data apply to all applicable functional data types within the datasheet and to all datasheets in the selection project. You change the parameter values using the Parameters hyperlink.

Note: The value for Fatigue strength model is calculated at the given parameter values for Stress ratio and Number of cycles.

❖ Find a record for STAINLESS STEEL

❖ Change the parameter value for NUMBER OF CYCLES

Click the **Parameters** link and set a new value in the dialog, then click **OK**. The value in the datasheet will be updated.



❖ View the updated project setting

Go to the **Select** menu and **Project Settings**. The updated settings are under the **Parameter Values** tab.

3.4 Find Similar with Additional Criteria

If a project has additional or different constraints than are captured by the default nearness criteria in Find Similar, there are two ways to refine the results.

Exercise 28 — Find Similar with Limits

❖ Open the record for POLYPROPYLENE (COPOLYMER, CONDUCTIVE, 5% CARBON POWDER)

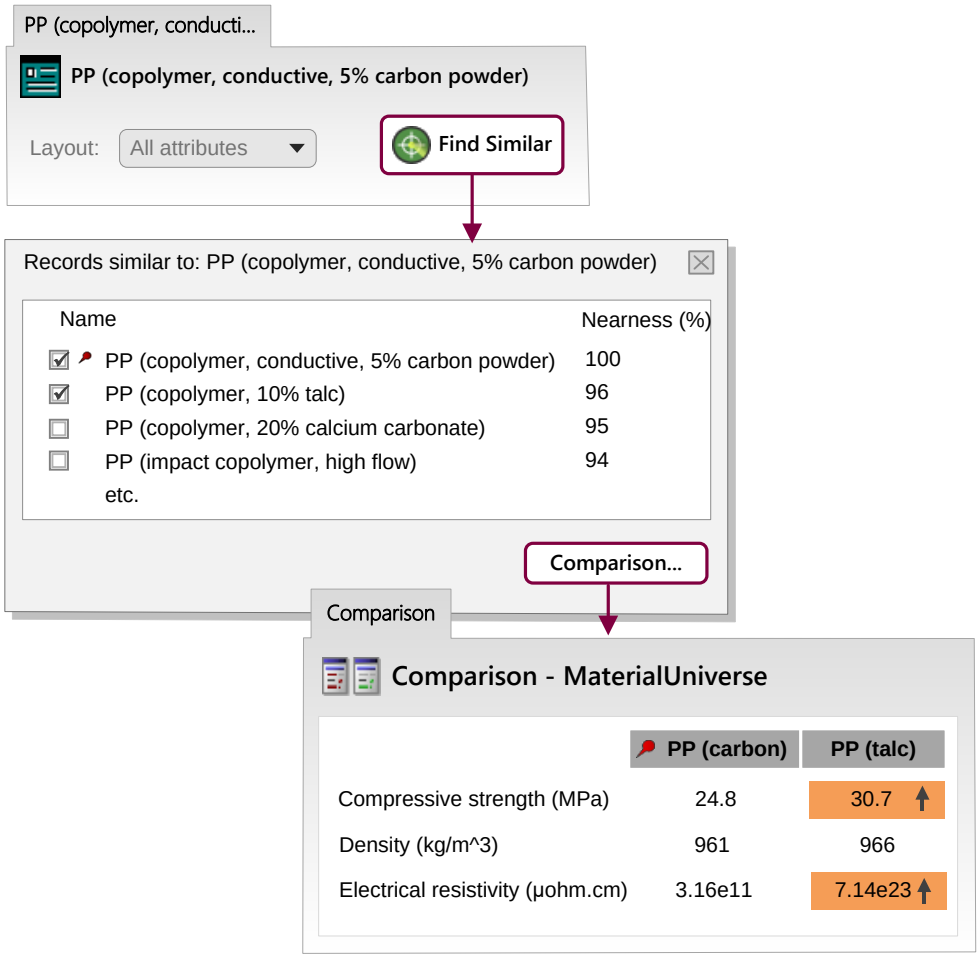
❖ Find records similar to this one

Click **Find Similar**. Use the default weightings to calculate nearness; do not open the Nearness Settings window.

❖ Compare the current material with the nearest alternative

Select the closest record from the list of results - **PP (copolymer, 10% talc)** - and open a comparison table using **Comparison**.

The comparison table is highlighted where there is a difference between the original (reference) and alternative materials. The reference material in this exercise was chosen specifically because it has low electrical resistivity, however the nearest match does not. This is because the default criteria for nearness in this table do not account for electrical resistivity. You can change this manually.



The nearest materials in the results have similar physical properties to the reference material (density, yield strength, Young's modulus). However, the original material may have been chosen for other characteristics. In this case, the polymer is conductive (has a low electrical resistivity).

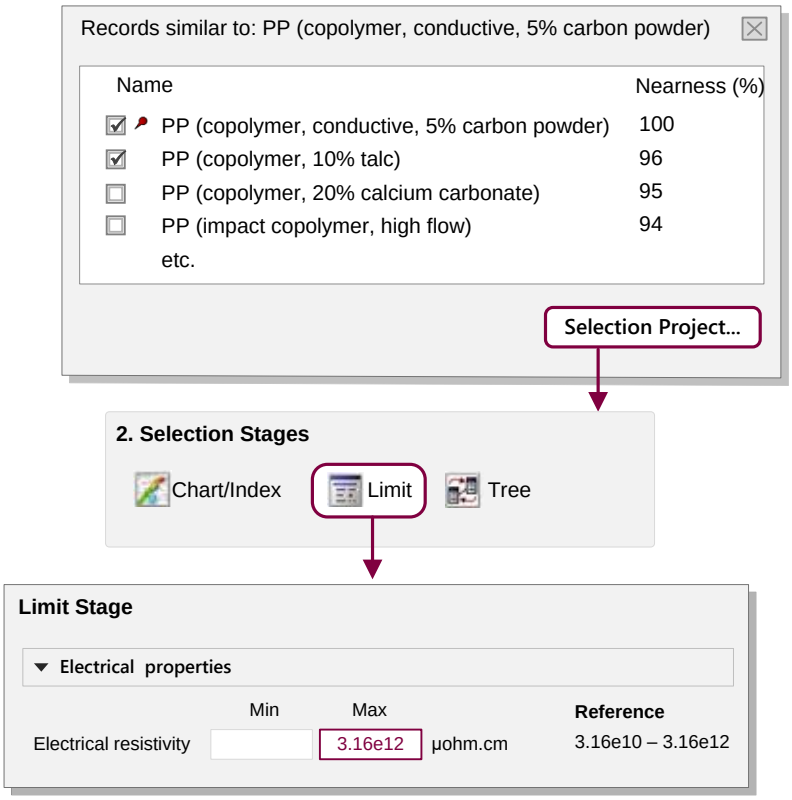
The results from Find Similar can be used as the basis of a Selection Project. In this case, you can use a Limit Stage to filter on the additional requirement for conductivity.

❖ Create a SELECTION PROJECT using the results

In the **Records similar to** dialog, click **Selection Project**. The results are loaded into a new project, ranked by nearness.

❖ Filter the results for electrical resistivity that is equal to or lower than the reference material

Create a Limit Stage, and set the maximum value for electrical resistivity to 3.16e12, which is the maximum value for the reference record. **Apply** the stage.



Example results, with Nearness (%):*PP (10-12%, stainless steel fiber)* 89%, *PP (10% carbon fiber)* 86%, *ABS (40% aluminum flake)* 84%.

❖ Delete this stage.

Exercise 29 — Changing the Find Similar Nearness Settings

Instead of filtering on additional attributes, it is possible to change the criteria used for calculating nearness to take account of different requirements.

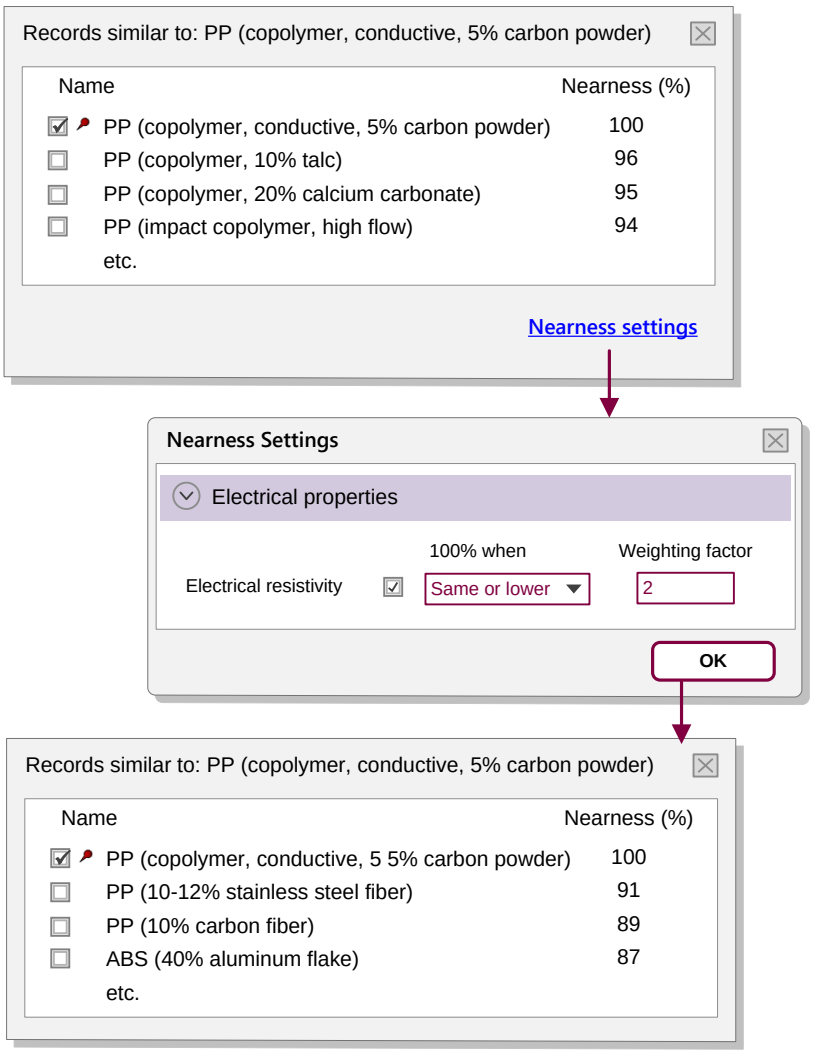
❖ Find records similar to POLYPROPYLENE (COPOLYMER, CONDUCTIVE, 5% CARBON POWDER)

Open the datasheet and click **Find Similar**.

❖ Re-calculate the list of alternative materials, taking ELECTRICAL RESISTIVITY into account and prioritizing those results with resistivity that is the same or lower than the reference

Click the **Nearness settings** link on the **Records Similar to** dialog.

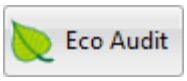
Under **Electrical Properties**, select **Electrical resistivity**, set it to **100% when Same or lower** and increase the Weighting factor to 2. Click **OK** to generate the new results.



Note that these results are conceptually different to those from the previous exercise. These results rank similar materials, taking into account the conductivity, but there is not a fixed upper limit as there was when filtering using the Limit Stage. Materials with a higher conductivity than the reference will still be included in these results.

3.5 Eco Audit

Only available in some CES Selector editions



The Eco Audit Tool, which is an optional add-on for CES Selector, estimates 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.

In this case study:

- 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 Selector in the *Samples* folder, with the filename Bottle mineral water.prd.

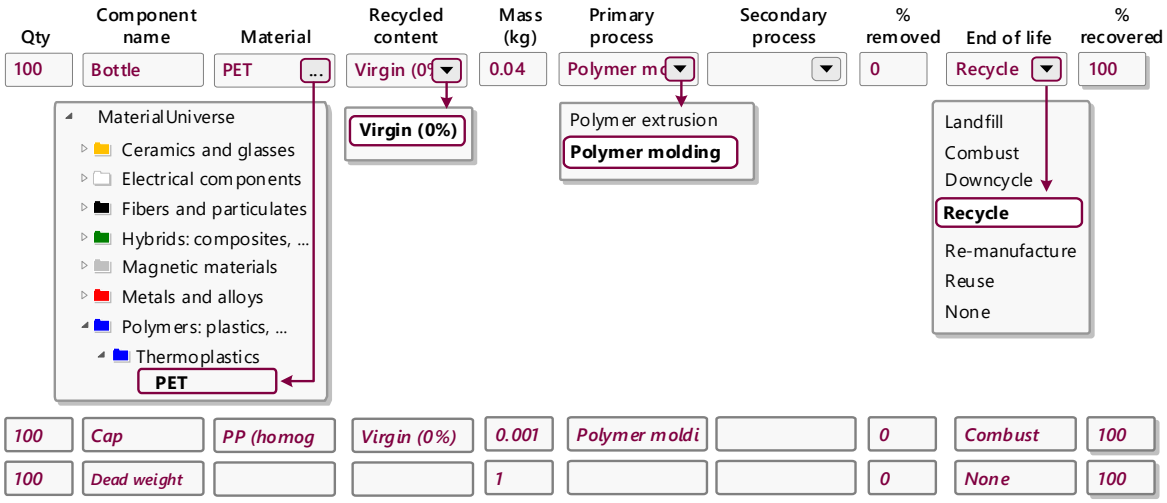
Product Definition

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

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

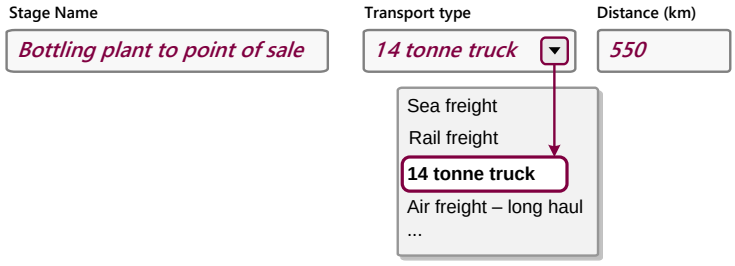
1. Material, manufacture, and end of life

Bill of materials (BoM), primary and (optional) secondary processing techniques.



2. Transport

Transportation from site of manufacture to point of sale.

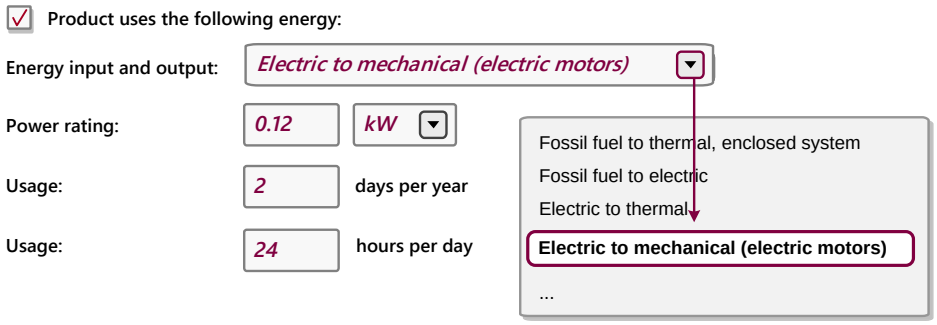


3. Use

Product Life and Location Use

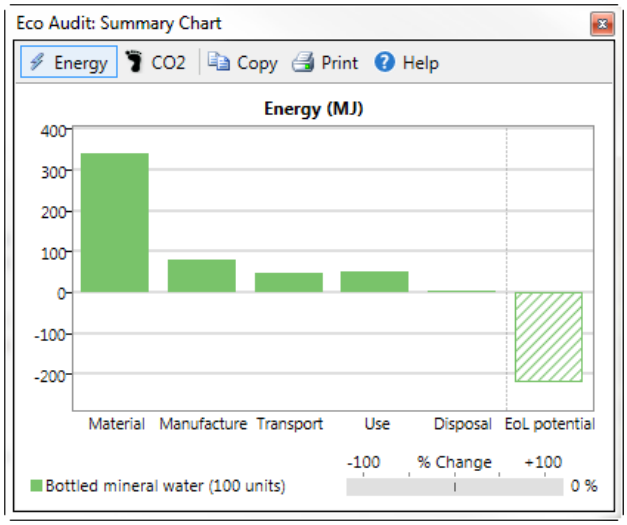
Static Mode

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



4. Report

Summary chart enables rapid identification of the dominant life phase. Toggle between views of energy usage or CO_2 footprint.



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.

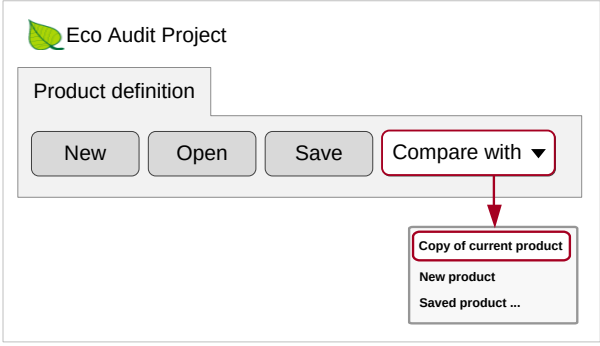
Exercise 30 — Compare Eco Audits

❖ Open the *Bottled mineral water* product file.

Click **Open** and locate the sample product file *Bottled mineral water.prd*, located in the Samples folder in your CES Selector installation folder. For example: *C:\Program files (x86)\CES Selector 2019\Samples\eco_audit\Bottled mineral water.prd*

❖ Create a copy of this product for comparison

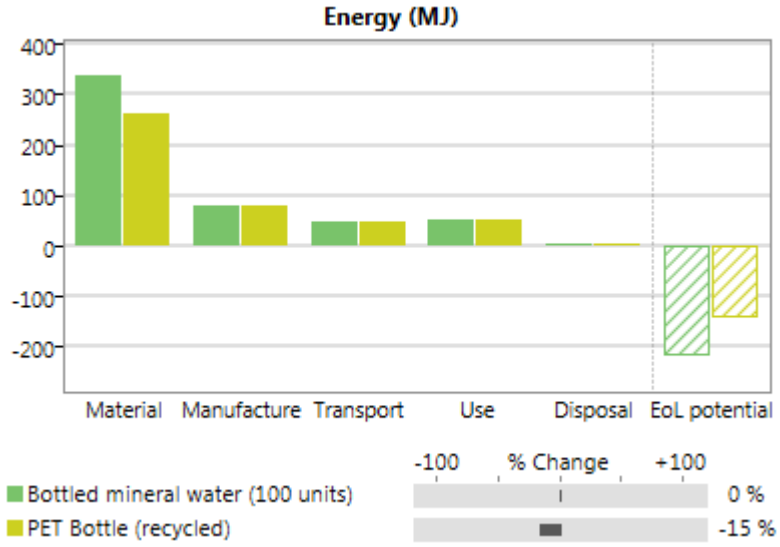
Click **Compare with** and select **Copy of current product**.



❖ Set the following values in for the new product:

NAME	PET Bottle (Recycled)
RECYCLED CONTENT	35%

❖ Generate the SUMMARY CHART



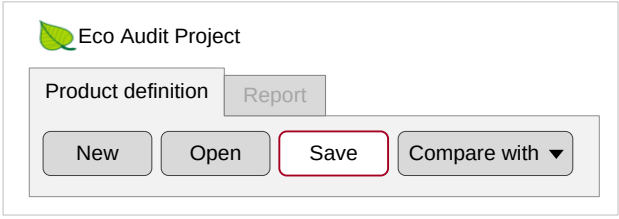
The first life energy (not including EoL potential) is reduced by 15%.

Note: You can copy the chart into a document or print it using Copy and Print at the top of the chart window.

Exercise 31 — Saving and Exporting

Eco Audit projects do not form part of a selection project and therefore you will need to save them separately.

❖ SAVE the product definition

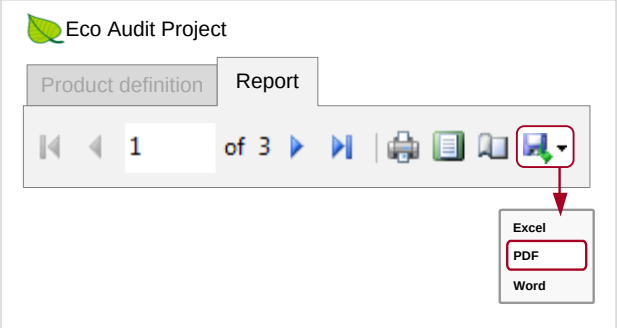


❖ GENERATE the Eco Audit report

Click the **Report** tab (or click **Detailed Report** on the Product definition tab).

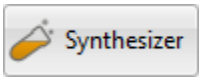
❖ EXPORT the report as a PDF

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



3.6 Synthesizer Tool

Only available in some CES Selector editions



The Synthesizer tool is designed for use in the early stage of product development. It consists of two types of models: ***hybrid models***, for estimating the performance of novel materials and structures; and the ***part cost estimator***, for calculating the cost of a component based on material and process chain.

The Synthesizer tool enables you to compare the performance of these materials with other materials in the MaterialUniverse database.

Exercise 32 — Sandwich Panels Model

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 to create strong, lightweight structures.

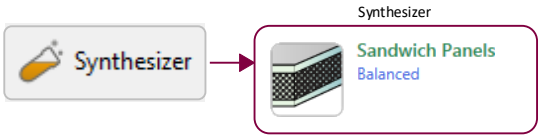
❖ Make a BUBBLE CHART of YOUNG'S MODULUS (E) against DENSITY (ρ) using MaterialUniverse: All bulk materials

As in Exercise 7.

❖ Use the SANDWICH PANELS MODEL to create synthesized records for a family of hybrid materials

Click **Synthesizer** on the toolbar (or click **Tools > Synthesizer** on the menu bar).

Select the *Sandwich Panels – Balanced* model.



❖ 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.

❖ Use the default values for MODEL VARIABLES and MODEL PARAMETERS, and set the following RECORD NAMING values:

FACE-SHEET	Al
CORE	Rohacell

❖ CREATE the synthesized records

Click **Create** and then **Finish**. The new synthesized records will be shown in the Results list and on the Chart Stage.

Note: The Help in the Synthesizer dialog opens further information about the current model type, including details of the calculations used.

❖ Plot an INDEX LINE corresponding to a lightweight, stiff panel in bending $E_f^{1/3}/\rho$

Click **Index line**, enter a slope of 3, and maximize the index.

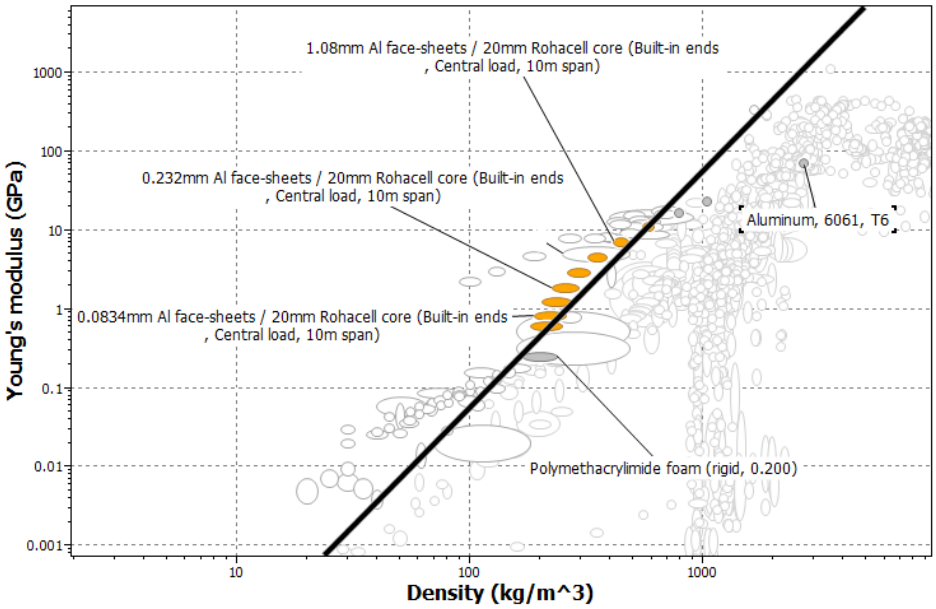
❖ Add labels to the source records and some of the synthesized records

You can select individual records on the chart and drag to place a label.

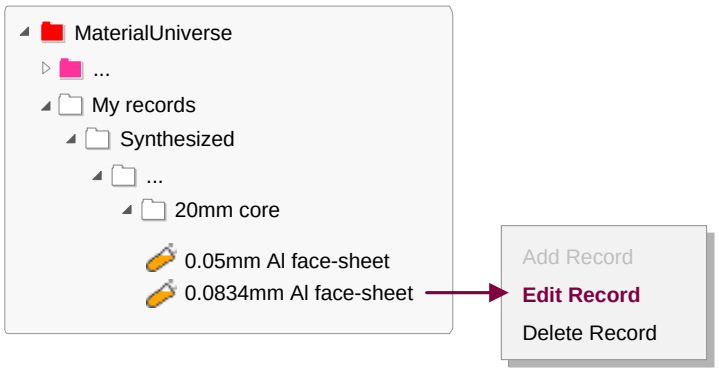
You can also add labels from the Results list: select one or more records in the Results list, right-click and select **Label** on the shortcut menu, then then drag the labels where you want them on the chart.

Click **Highlight synthesized records** to help you identify the synthesized records on the chart.

Use the Zoom controls and to zoom in to the area of interest on the chart.



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

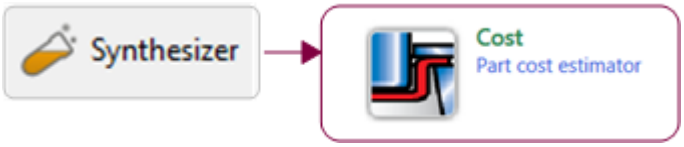


Exercise 33 — Part Cost Estimator

The Part Cost Estimator is a synthesizer model that calculates the total cost of a component based on the material and processing costs.

❖ Use the Part Cost Estimator to compare the cost of a component manufactured in two different ways: as an injection molded polymer, and as a rolled and pressed metal.

Start Synthesizer Tool by clicking **Synthesizer** on the toolbar and in the dialog, select *Cost – Part cost estimator*.



❖ Set the COMPONENT DETAILS:

MATERIAL	PP (copolymer, 20% talc)
VALUE OF SCRAP MATERIAL	10%
PART MASS	6.4
PART LENGTH	10
BATCH SIZE	1000 - 1E6
NUMBER OF VALUES	10

Note: for this exercise, the units of part mass and part length do not matter.

❖ Set the PRIMARY SHAPING PROCESS values:

PRIMARY PROCESS	Injection molding (thermoplastics)
AVAILABILITY	Custom form
PART COMPLEXITY	Standard

Use the default values for load factor, overhead rate, and capital write-off time.

❖ Set the RECORD NAMING values:

MATERIAL	PP
PRIMARY PROCESS	molded

❖ Create the new records.

Click **Create**. Keep the Part Cost Estimator window open.

The new synthesized records will be shown in the Results list and on the Chart Stage.

❖ Add another material process.

In the Part Cost Estimator window, click **Previous** and set the COMPONENT DETAILS for another material processing chain:

MATERIAL	YS170 (hot rolled) high strength steel
PART MASS	10

Use the default values for scrap material value, part length, batch size, and number of values (retained from the first material processing chain input).

❖ Set the PRIMARY SHAPING PROCESS values:

PRIMARY PROCESS	Hot shape rolling

Use the default values for the other properties.

❖ Set the SECONDARY SHAPING PROCESS.

Select **Include secondary process**, and enter the following value:

SECONDARY PROCESS	Press forming

Use the default values for part complexity, amount of scrap, and scap recycled.

❖ Set the RECORD NAMING values:

MATERIAL	Steel
PRIMARY PROCESS	rolled
SECONDARY PROCESS	pressed

❖ Click **Create** and then **Finish** to create the synthesized records and close the Part Cost Estimator.

Synthesized records created using Part Cost Estimator are appended to the MaterialUniverse tree under My records > Synthesized > Part cost estimator.

❖ Create a bubble chart to compare the two material processing chains.

Click **Chart/Index** and set the following x- and y-axis values:

CATEGORY	Part cost estimator
X-AXIS ATTRIBUTE	Batch size
Y-AXIS ATTRIBUTE	Part cost

❖ Change the record color for easy comparison of the two processing chains.

On the MaterialUniverse browse tree, navigate to My records > Synthesized > Part cost estimator.

Right-click the ***PP, molded*** subfolder, click Record color, and click a color to change the record color for all records in that folder.