Materials 2:
Granta and Materials Selection

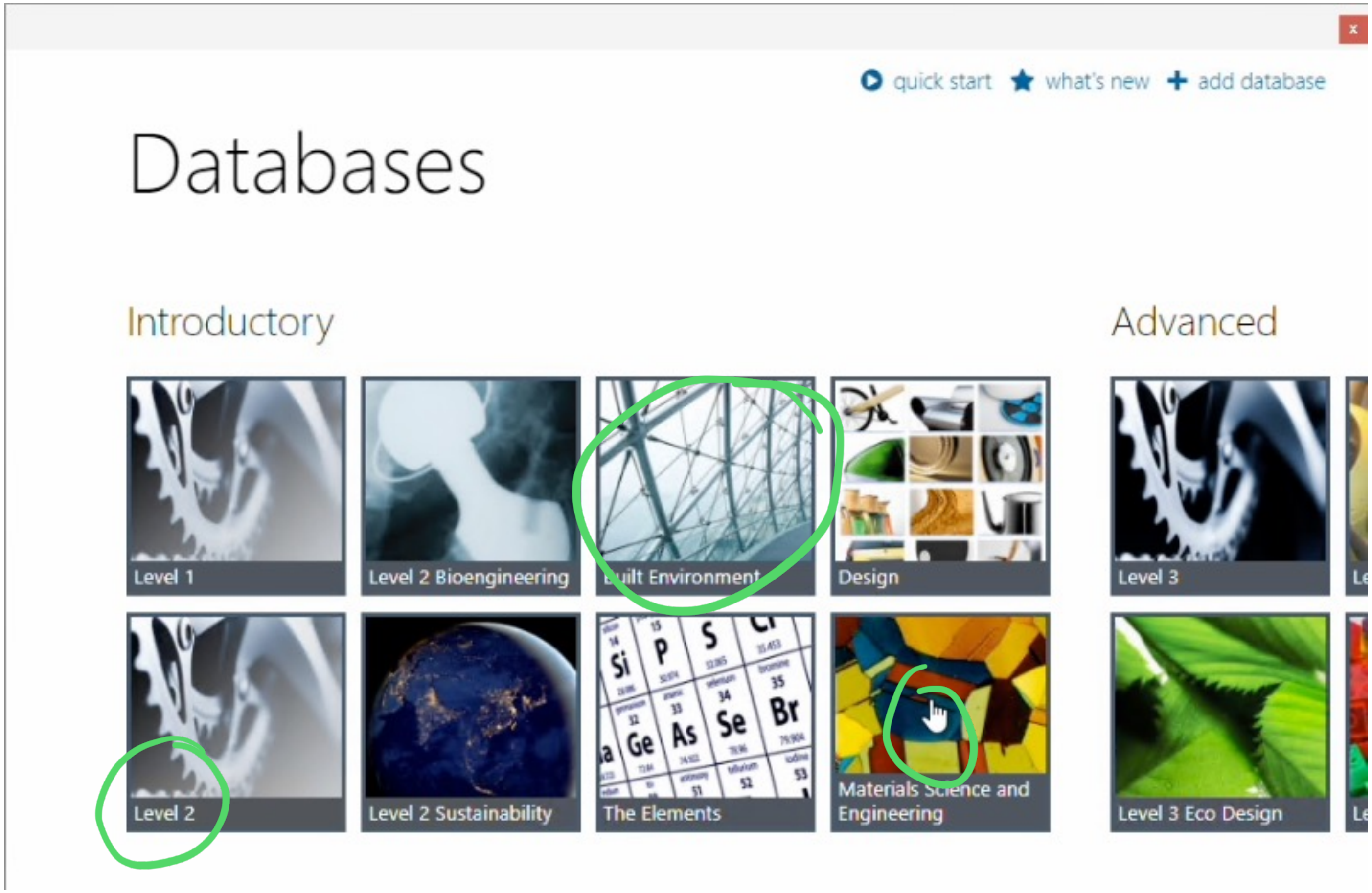
Tom Reynolds

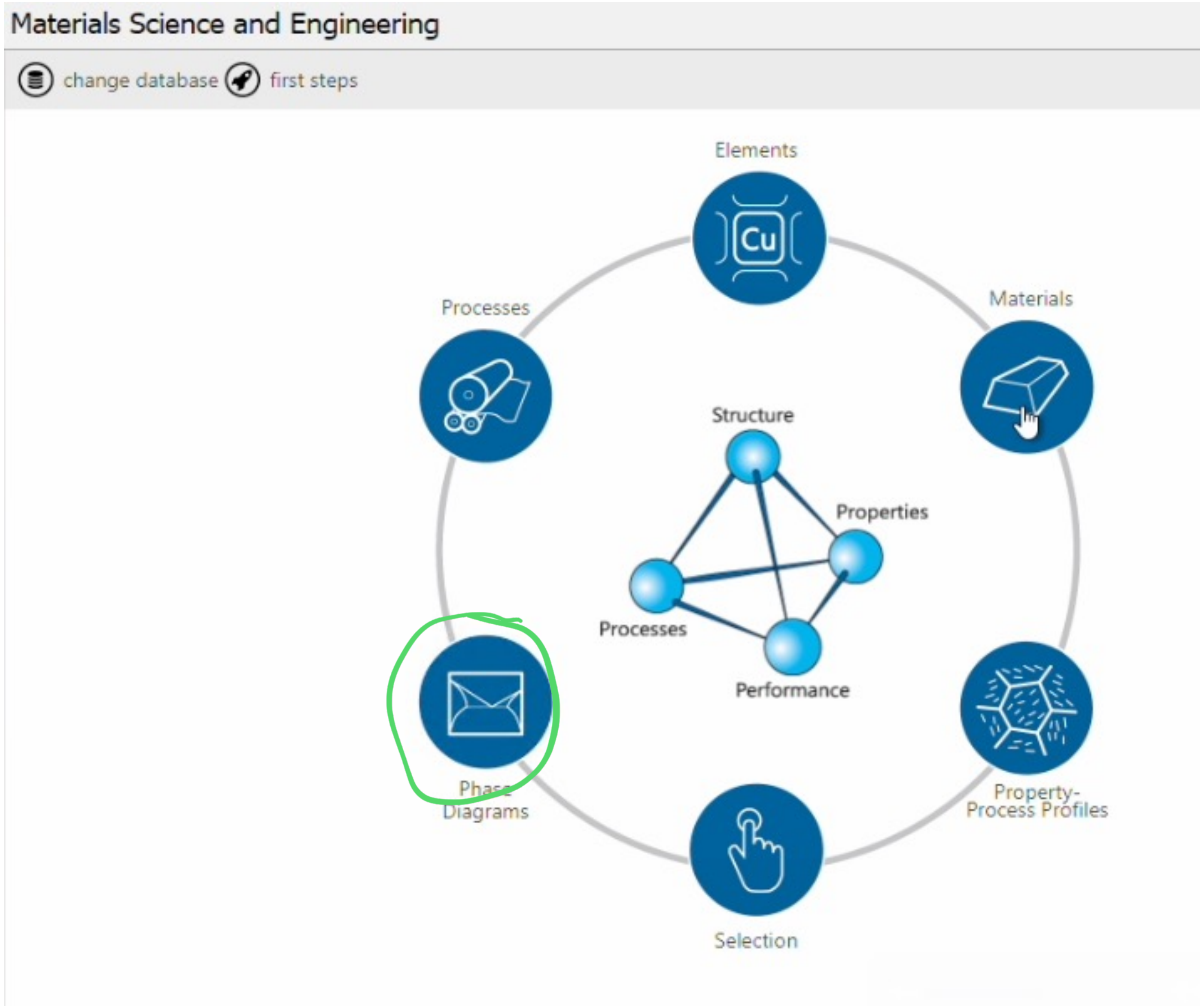
Granta Software

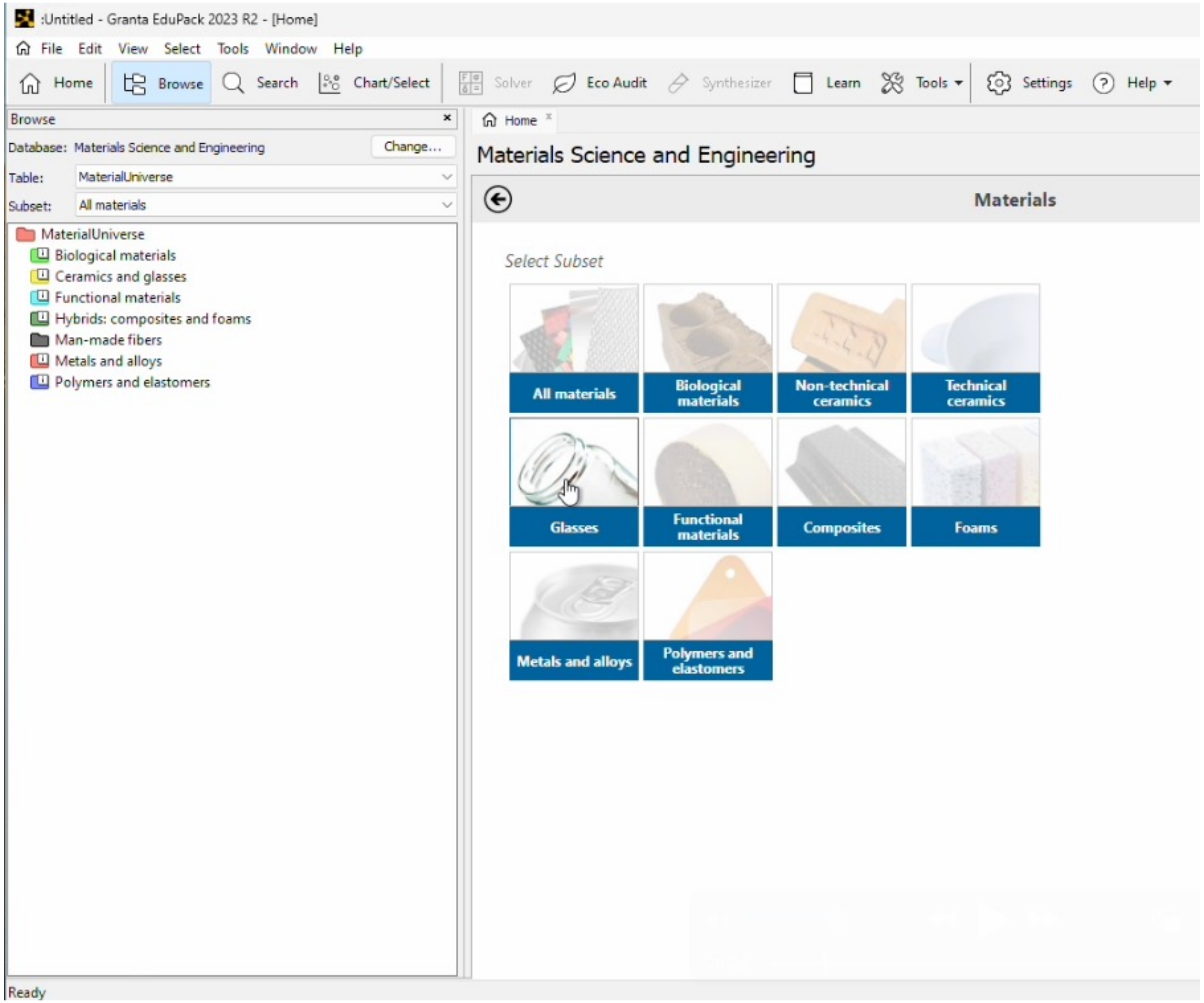
- A reliable (not infallible) source of material data
- Use it:
  - During this course to answer questions, check your measurements

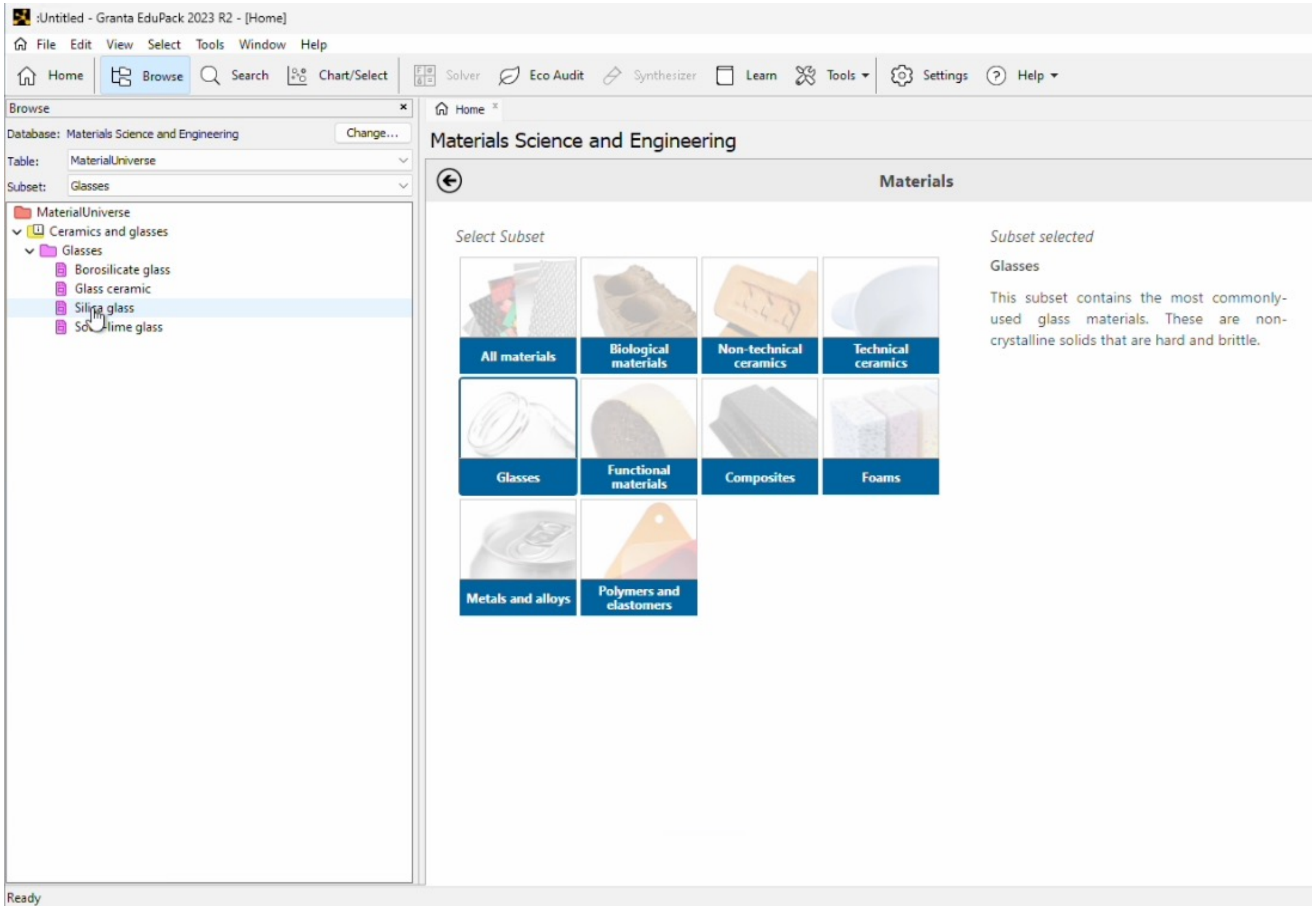
Granta Software

- A reliable (not infallible) source of material data
- Use it:
  - During this course to answer questions, check your measurements
  - For future courses and engineering societies


quick start
what's new
add database
Databases
Introductory
Advanced
Level 1
Level 2 Bioengineering
uilt Environment
Design
Level 3
Level 2
Level 2 Sustainability
The Elements
Materials Science and Engineering
Level 3 Eco Design


Materials Science and Engineering
change database
first steps
Elements
Cu
Processes
Materials
Structure
Properties
Processes
Performance
Phase
Diagrams
Property-
Process Profiles
Selection


:Untitled - Granta EduPack 2023 R2 - [Home]
File Edit View Select Tools Window Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help
Browse
Database: Materials Science and Engineering
Change...
Table: MaterialUniverse
Subset: All materials
MaterialUniverse
Biological materials
Ceramics and glasses
Functional materials
Hybrids: composites and foams
Man-made fibers
Metals and alloys
Polymers and elastomers
Home
Materials Science and Engineering
Materials
Select Subset
All materials
Biological materials
Non-technical ceramics
Technical ceramics
Glasses
Functional materials
Composites
Foams
Metals and alloys
Polymers and elastomers
Ready



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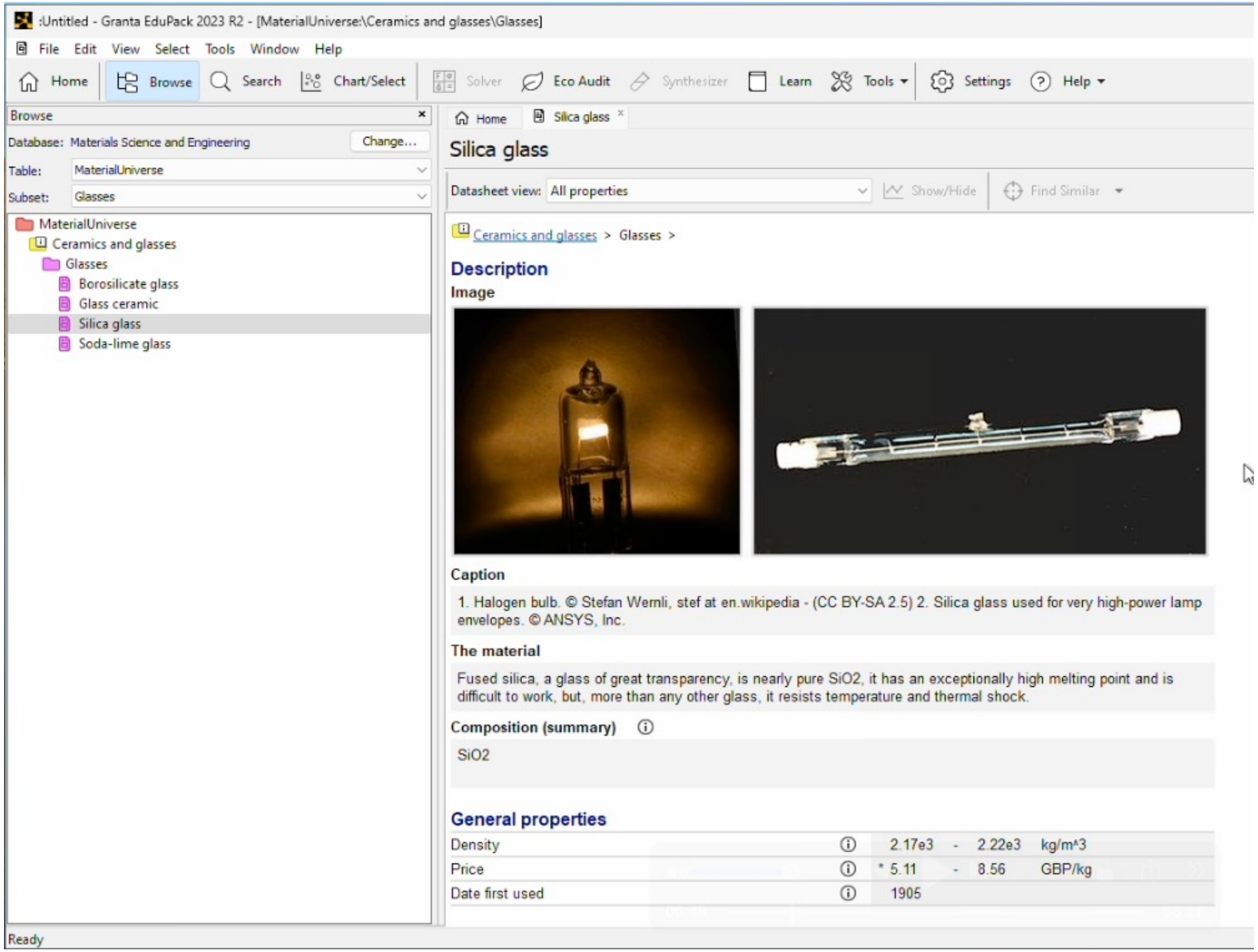
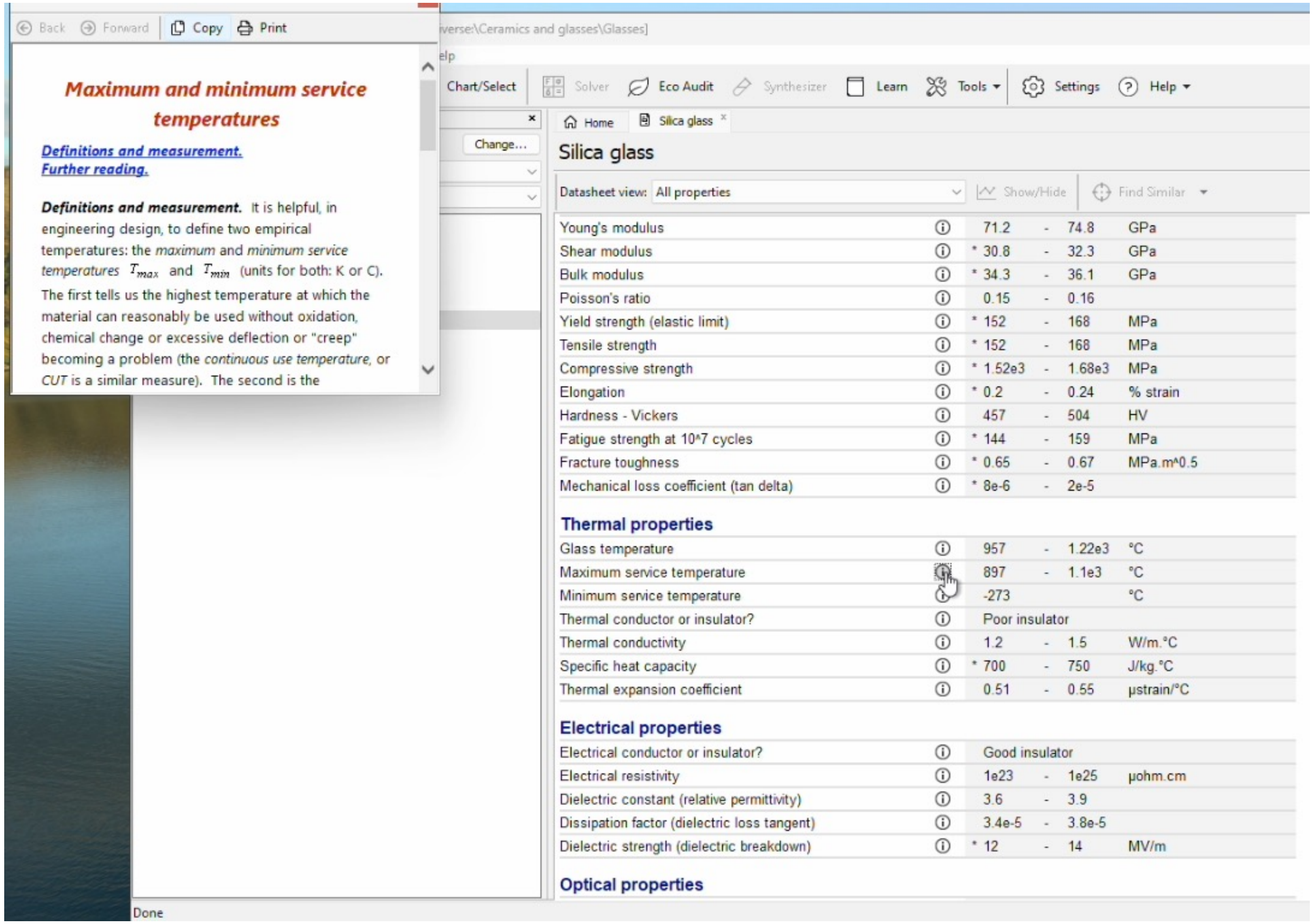
File Edit View Select Tools Window Help
Home
Browse
Search
Chart/Select
Solver
Eco Audit
Synthesizer
Learn
Tools
Settings
Help
Browse
Database: Materials Science and Engineering
Change...
Table: MaterialUniverse
Subset: Glasses
MaterialUniverse
Ceramics and glasses
Glasses
Borosilicate glass
Glass ceramic
Silica glass
Soda-lime glass
Home
Materials Science and Engineering
Materials
Select Subset
All materials
Biological materials
Non-technical ceramics
Technical ceramics
Glasses
Functional materials
Composites
Foams
Metals and alloys
Polymers and elastomers
Subset selected
Glasses
This subset contains the most commonly-used glass materials. These are non-crystalline solids that are hard and brittle.
Ready


:Untitled - Granta EduPack 2023 R2 - [MaterialUniverse:\Ceramics and glasses\Glasses]
File Edit View Select Tools Window Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help
Browse
Database: Materials Science and Engineering
Change...
Table: MaterialUniverse
Subset: Glasses
MaterialUniverse
Ceramics and glasses
Glasses
Borosilicate glass
Glass ceramic
Silica glass
Soda-lime glass
Home
Silica glass
Silica glass
Datasheet view: All properties
Show/Hide
Find Similar
Ceramics and glasses > Glasses >
Description
Image
Caption
1. Halogen bulb. © Stefan Wernli, stef at en.wikipedia - (CC BY-SA 2.5) 2. Silica glass used for very high-power lamp envelopes. © ANSYS, Inc.
The material
Fused silica, a glass of great transparency, is nearly pure SiO2, it has an exceptionally high melting point and is difficult to work, but, more than any other glass, it resists temperature and thermal shock.
Composition (summary)
SiO2
General properties
Density 2.17e3 - 2.22e3 kg/m^3
Price * 5.11 - 8.56 GBP/kg
Date first used 1905
Ready



Back
Forward
Copy
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Maximum and minimum service temperatures
Definitions and measurement.
Further reading.
Definitions and measurement. It is helpful, in engineering design, to define two empirical temperatures: the maximum and minimum service temperatures Tmax and Tmin (units for both: K or C). The first tells us the highest temperature at which the material can reasonably be used without oxidation, chemical change or excessive deflection or "creep" becoming a problem (the continuous use temperature, or CUT is a similar measure). The second is the
verse\Ceramics and glasses\Glasses]
Chart/Select
Solver
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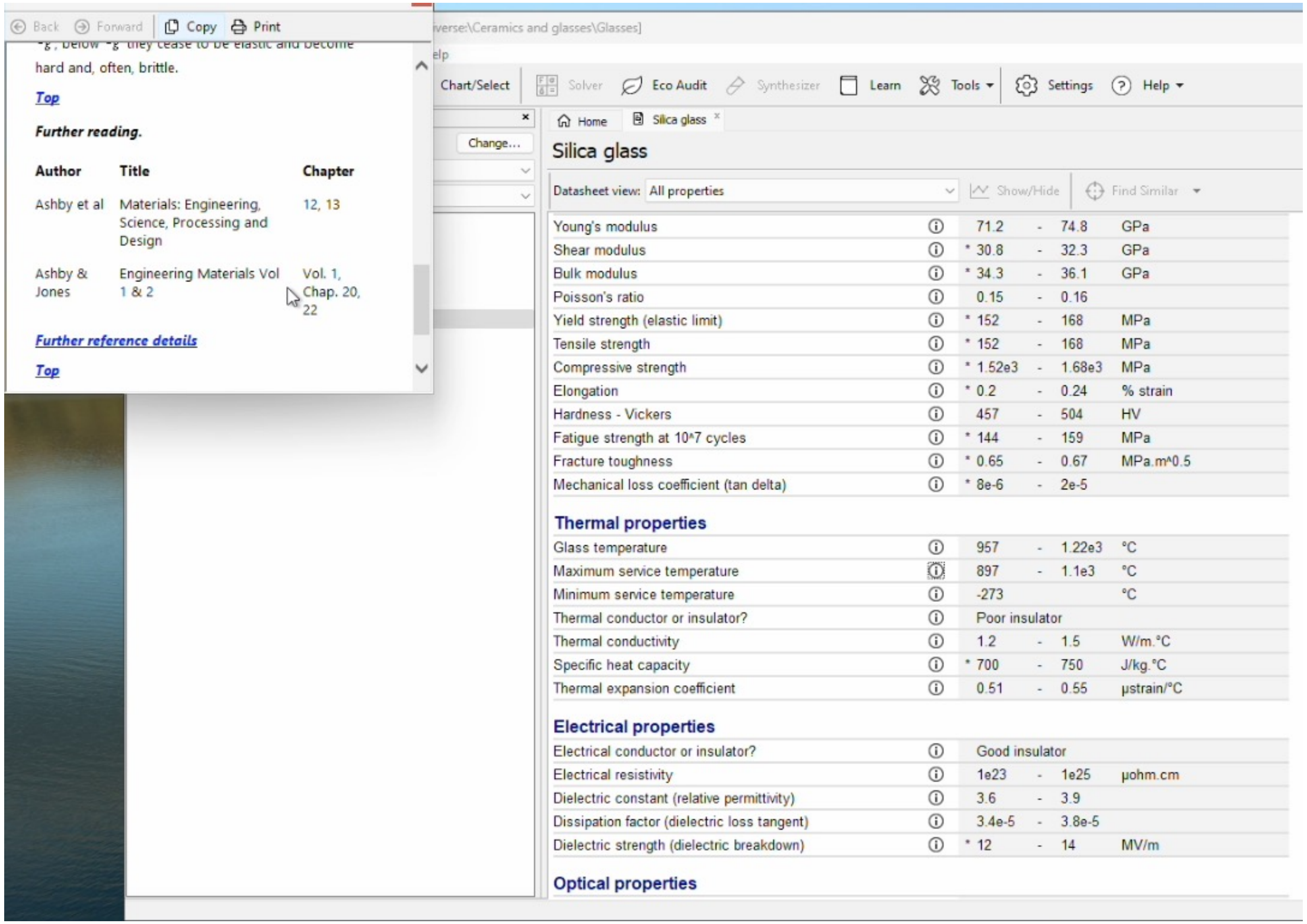
Help
Change...
Home
Silica glass
Silica glass
Datasheet view: All properties
Show/Hide
Find Similar
Young's modulus 71.2 - 74.8 GPa
Shear modulus * 30.8 - 32.3 GPa
Bulk modulus * 34.3 - 36.1 GPa
Poisson's ratio 0.15 - 0.16
Yield strength (elastic limit) * 152 - 168 MPa
Tensile strength * 152 - 168 MPa
Compressive strength * 1.52e3 - 1.68e3 MPa
Elongation * 0.2 - 0.24 % strain
Hardness - Vickers 457 - 504 HV
Fatigue strength at 10^7 cycles * 144 - 159 MPa
Fracture toughness * 0.65 - 0.67 MPa.m^0.5
Mechanical loss coefficient (tan delta) * 8e-6 - 2e-5
Thermal properties
Glass temperature 957 - 1.22e3 °C
Maximum service temperature 897 - 1.1e3 °C
Minimum service temperature -273 °C
Thermal conductor or insulator? Poor insulator
Thermal conductivity 1.2 - 1.5 W/m.°C
Specific heat capacity * 700 - 750 J/kg.°C
Thermal expansion coefficient 0.51 - 0.55 µstrain/°C
Electrical properties
Electrical conductor or insulator? Good insulator
Electrical resistivity 1e23 - 1e25 µohm.cm
Dielectric constant (relative permittivity) 3.6 - 3.9
Dissipation factor (dielectric loss tangent) 3.4e-5 - 3.8e-5
Dielectric strength (dielectric breakdown) * 12 - 14 MV/m
Optical properties
Done


Back
Forward
Copy
Print
hard and, often, brittle.
Top
Further reading.
Author
Title
Chapter
Ashby et al
Materials: Engineering, Science, Processing and Design
12, 13
Ashby & Jones
Engineering Materials Vol 1 & 2
Vol. 1, Chap. 20, 22
Further reference details
Top
verse:\Ceramics and glasses\Glasses]
Chart/Select
Solver
Eco Audit
Synthesizer
Learn
Tools
Settings
Help
Change...
Home
Silica glass
Silica glass
Datasheet view: All properties
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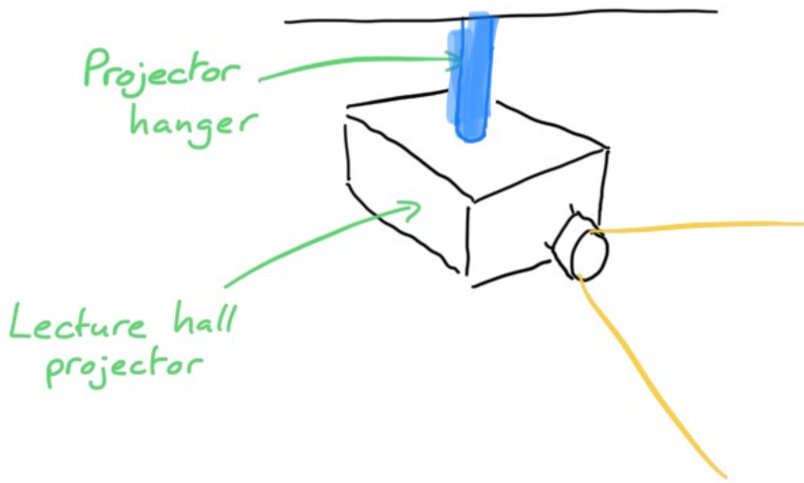
Dielectric strength (dielectric breakdown) * 12 - 14 MV/m
Optical properties

Example: Select a material to hang projectors

The university has ordered 1000 new projectors to install in lecture theatres.

They need to be hung from the ceiling, and the university wants to minimize the carbon footprint of this work.

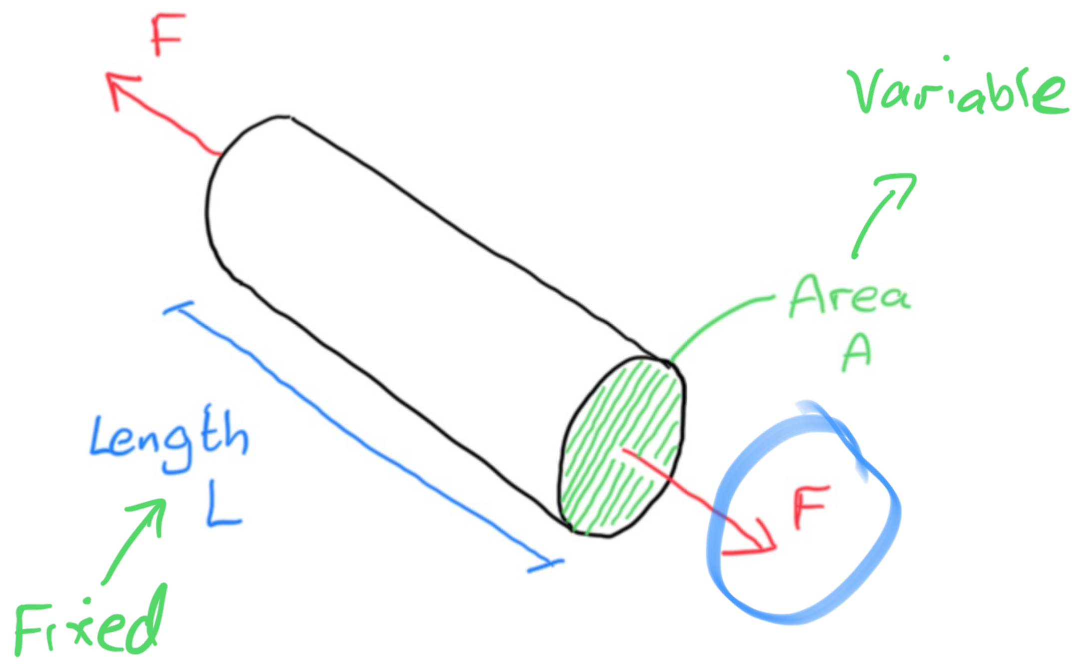
Choose a material for the hangers to support the projectors with minimum embodied carbon.



Define the problem

Resist force F

Minimise embodied carbon (CO_{2e})

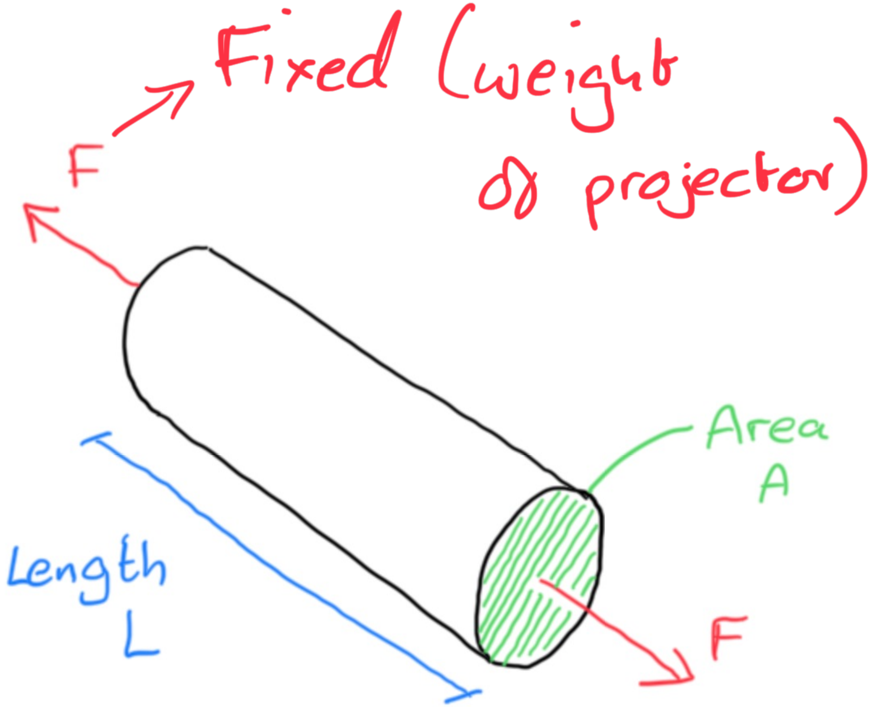


Define the problem

Calculate F, the force that can be resisted

$$F_d = \sigma \times A$$

yield stress

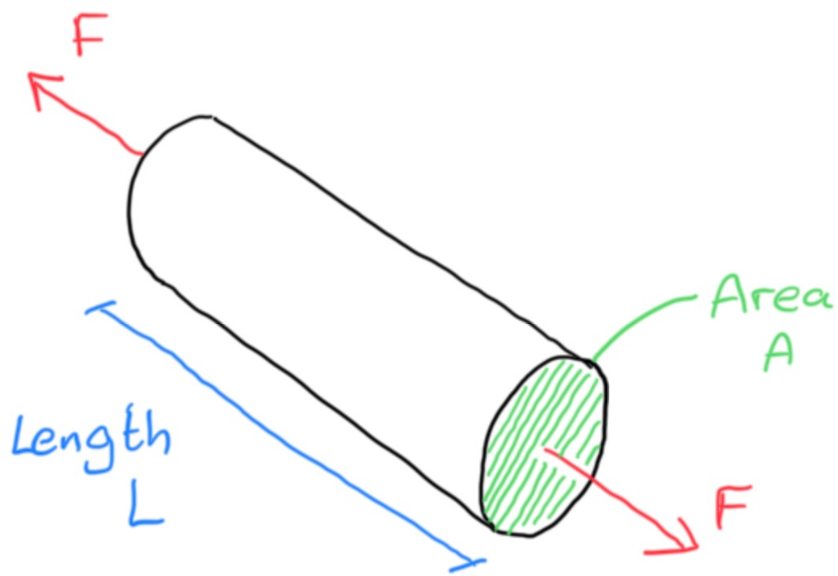


Define the problem

Calculate F, the force that can be resisted

$$F = \sigma_y \times A$$

... so we need the yield strength of the material

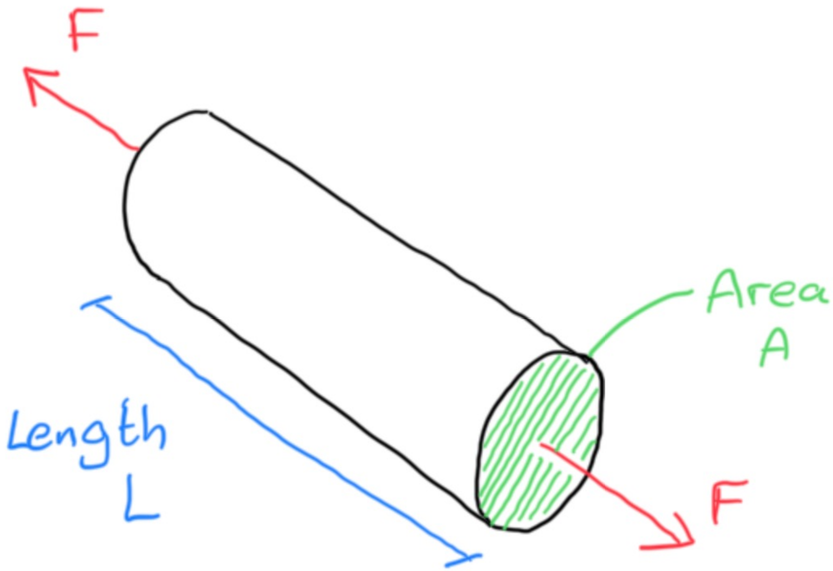


Define the problem

Calculate CO_2e:

Carbon dioxide equivalent

- Density
- Embodied carbon per kg



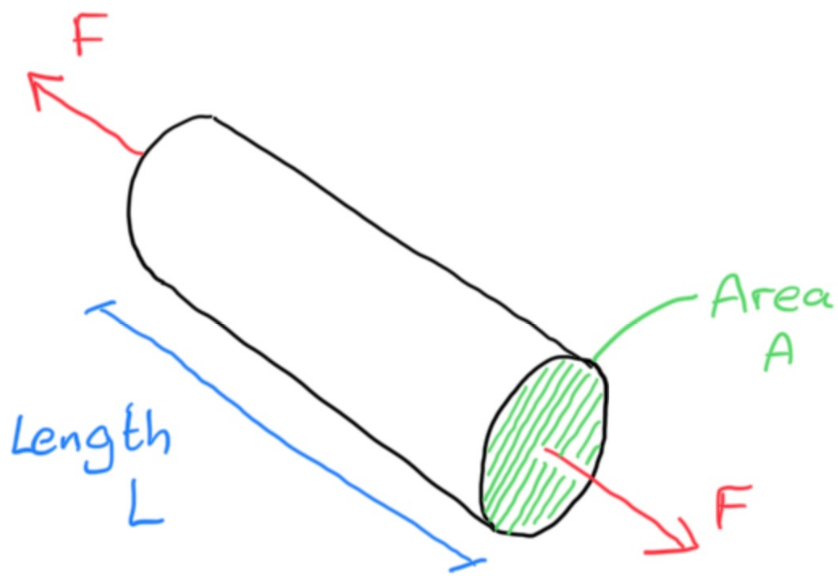
Define the problem

Calculate CO_2e:

$$CO_2e = c \times m$$

… m is the mass, and c is the embodied carbon per kg

$m = \rho \times V = \rho \times A \times L$



Define the problem

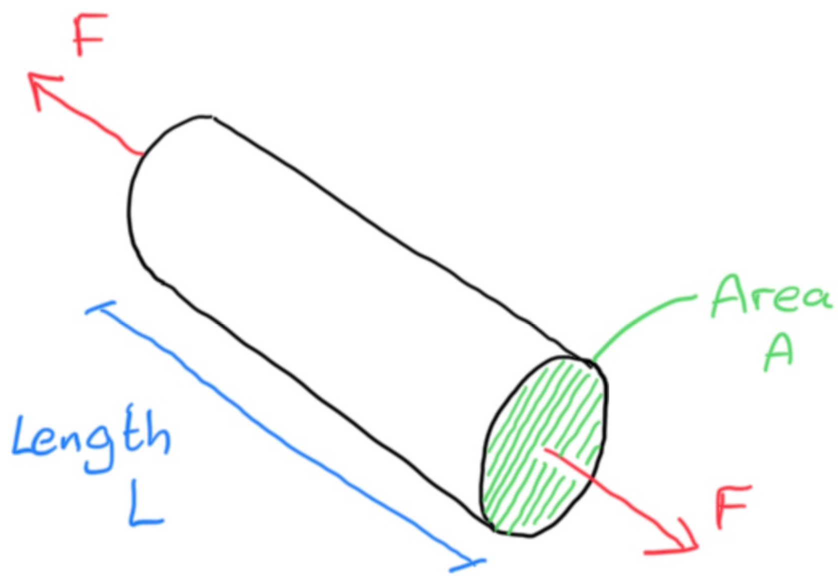
Calculate CO_2e:

$$CO_2e = c \times m$$

… m is the mass, and c is the embodied carbon per kg

"Carbon Footprint" in Granta

$$CO_2e = V \times \rho \times c$$
$$= A \times L \times \rho \times c$$

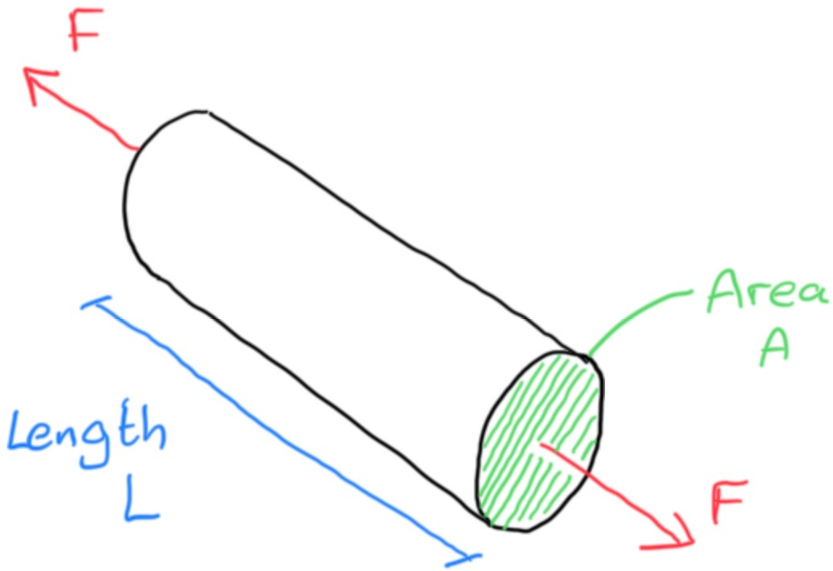


But wait…

Calculate CO_2e:

$$CO_2e = A \times L \times \rho \times c$$

… this depends on area too



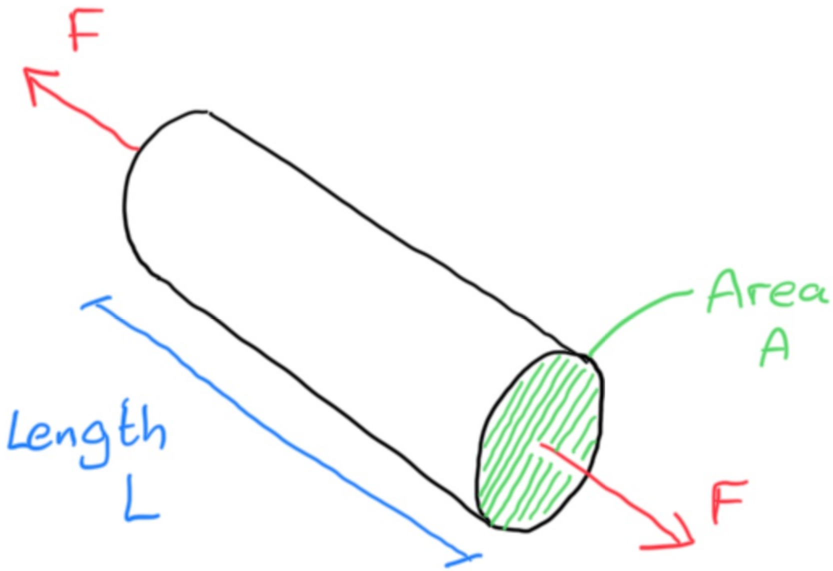
But wait…

We can allow for this by looking for the minimum of:

$$\frac{CO_2e}{F}$$

$$= \frac{\cancel{A} \times L \times \rho \times c}{\sigma_y \times \cancel{A}}$$

$$= \left(\frac{\rho c}{\sigma_y}\right) \times L$$

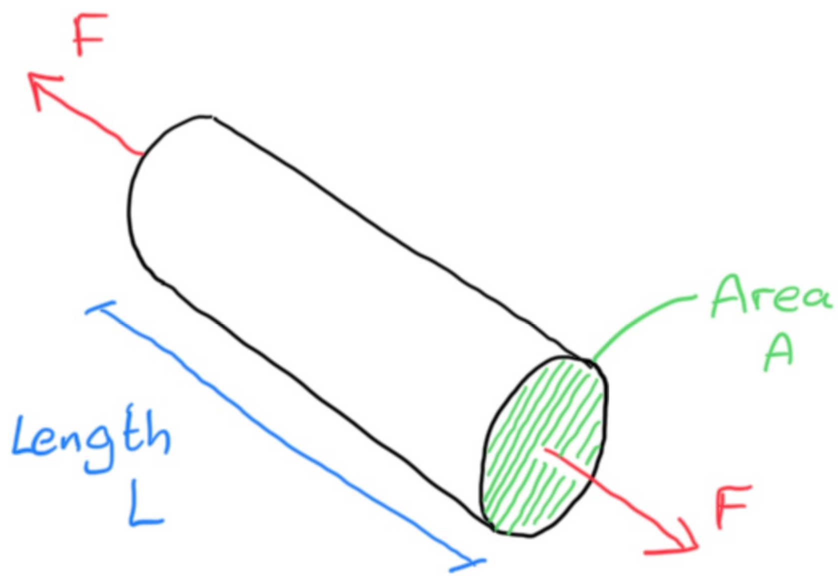


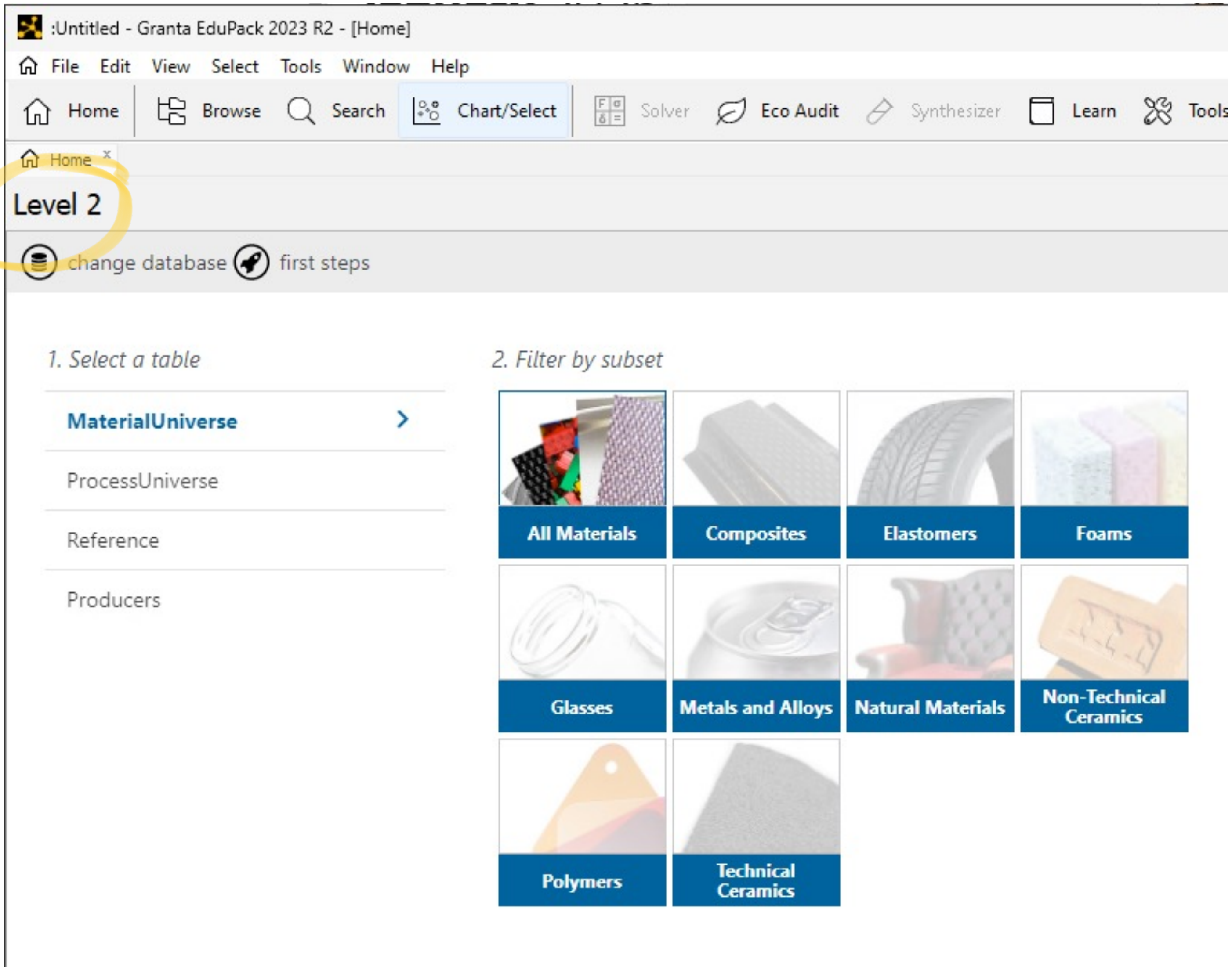
But wait…

We can allow for this by looking for the minimum of:

$$\frac{CO_2e}{F} = \frac{\rho c}{\sigma_y} \times L$$

… so let's plot density times carbon footprint against yield stress.

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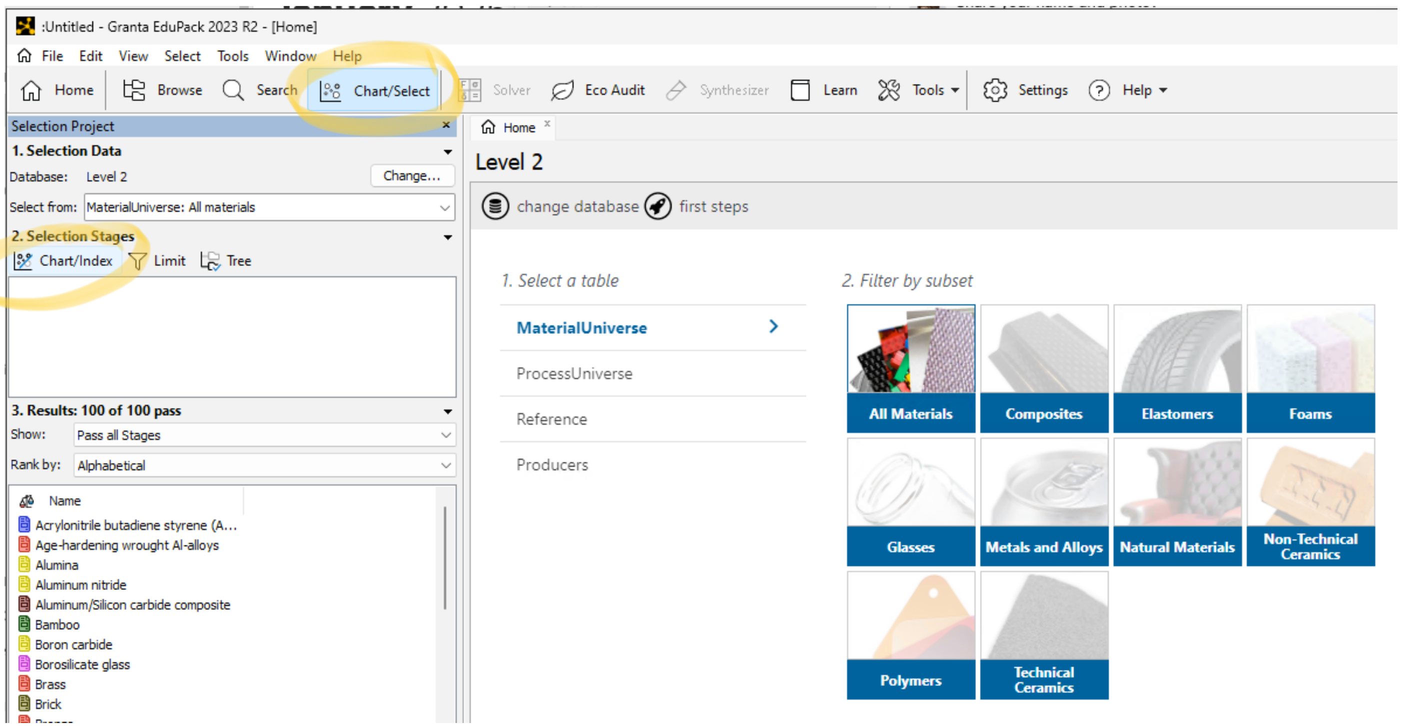
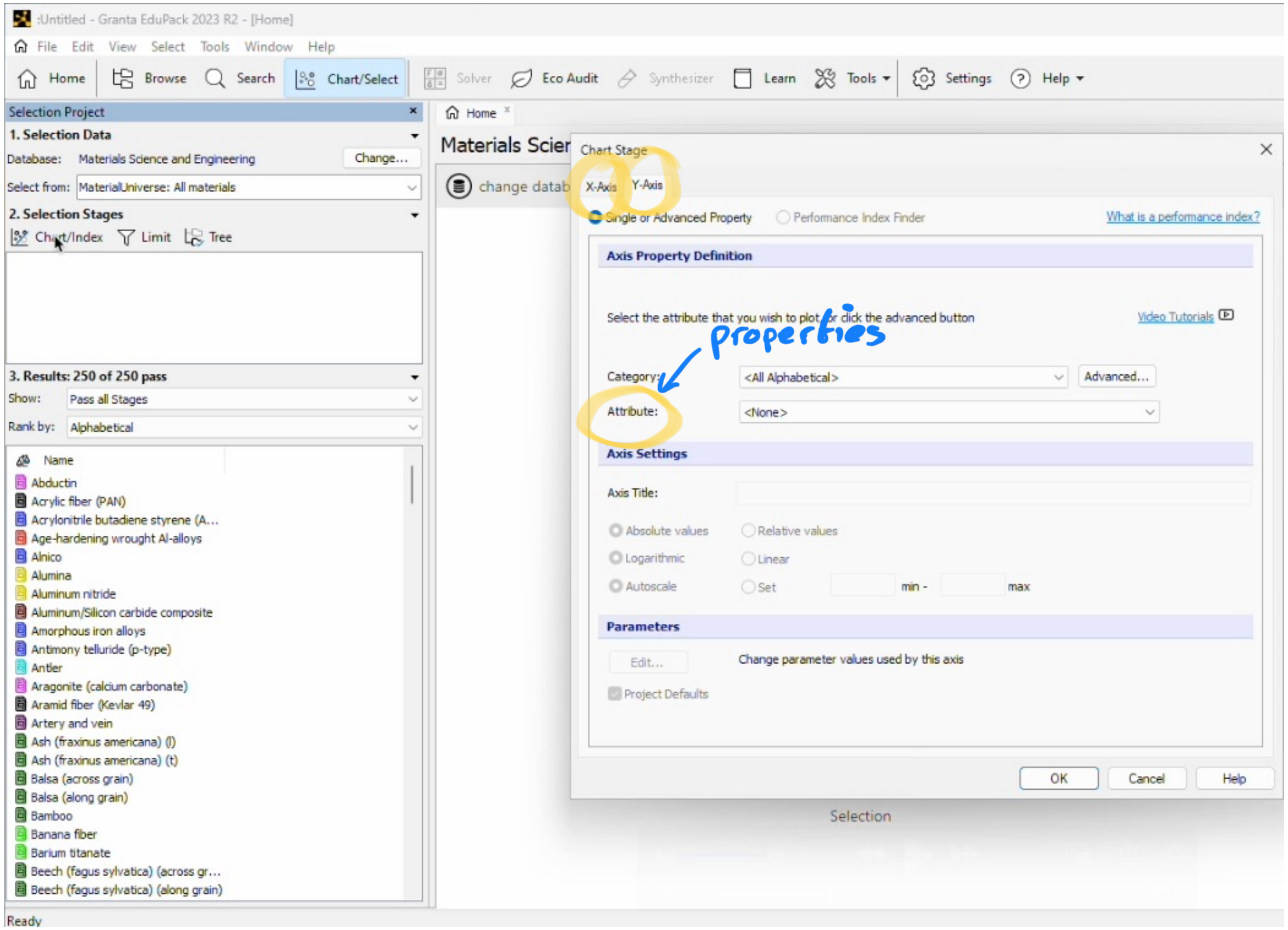
File Edit View Select Tools Window Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools
Home
Level 2
change database first steps
1. Select a table
MaterialUniverse
ProcessUniverse
Reference
Producers
2. Filter by subset
All Materials
Composites
Elastomers
Foams
Glasses
Metals and Alloys
Natural Materials
Non-Technical Ceramics
Polymers
Technical Ceramics


:Untitled - Granta EduPack 2023 R2 - [Home]
File Edit View Select Tools Window Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help
Selection Project
1. Selection Data
Database: Level 2
Change...
Select from: MaterialUniverse: All materials
2. Selection Stages
Chart/Index Limit Tree
3. Results: 100 of 100 pass
Show: Pass all Stages
Rank by: Alphabetical
Name
Acrylonitrile butadiene styrene (A...
Age-hardening wrought Al-alloys
Alumina
Aluminum nitride
Aluminum/Silicon carbide composite
Bamboo
Boron carbide
Borosilicate glass
Brass
Brick
Home
Level 2
change database
first steps
1. Select a table
MaterialUniverse
ProcessUniverse
Reference
Producers
2. Filter by subset
All Materials
Composites
Elastomers
Foams
Glasses
Metals and Alloys
Natural Materials
Non-Technical Ceramics
Polymers
Technical Ceramics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File Edit View Select Tools Window Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help
Selection Project
1. Selection Data
Database: Materials Science and Engineering
Change...
Select from: MaterialUniverse: All materials
2. Selection Stages
Chart/Index Limit Tree
3. Results: 250 of 250 pass
Show: Pass all Stages
Rank by: Alphabetical
Name
Abductin
Acrylic fiber (PAN)
Acrylonitrile butadiene styrene (A...
Age-hardening wrought Al-alloys
Alnico
Alumina
Aluminum nitride
Aluminum/Silicon carbide composite
Amorphous iron alloys
Antimony telluride (p-type)
Antler
Aragonite (calcium carbonate)
Aramid fiber (Kevlar 49)
Artery and vein
Ash (fraxinus americana) (l)
Ash (fraxinus americana) (t)
Balsa (across grain)
Balsa (along grain)
Bamboo
Banana fiber
Barium titanate
Beech (fagus sylvatica) (across gr...
Beech (fagus sylvatica) (along grain)
Ready
Home
Materials Scier
change datab
Chart Stage
X-Axis Y-Axis
Single or Advanced Property
Performance Index Finder
What is a performance index?
Axis Property Definition
Select the attribute that you wish to plot or click the advanced button
Video Tutorials
properties
Category:
<All Alphabetical>
Advanced...
Attribute:
<None>
Axis Settings
Axis Title:
Absolute values
Relative values
Logarithmic
Linear
Autoscale
Set
min -
max
Parameters
Edit...
Change parameter values used by this axis
Project Defaults
OK Cancel Help
Selection

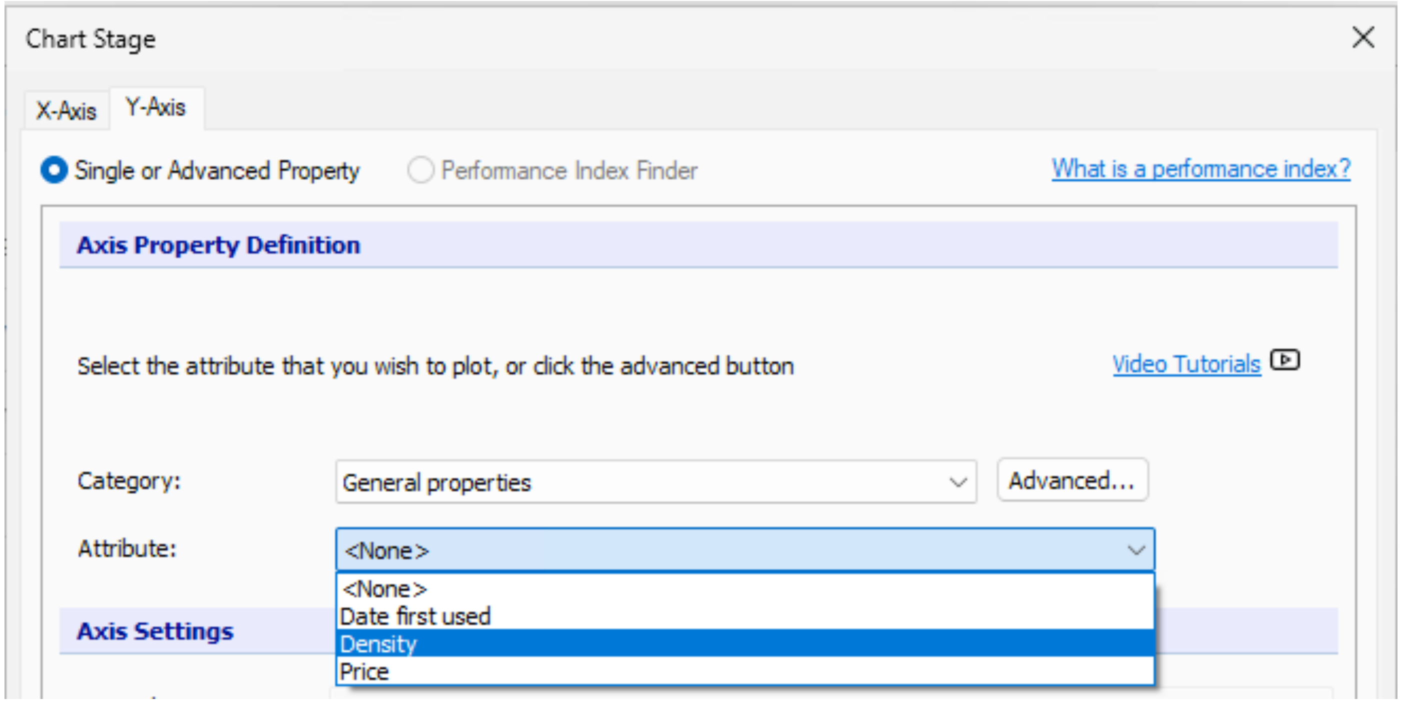


Chart Stage
X-Axis
Y-Axis
Single or Advanced Property
Performance Index Finder
What is a performance index?
Axis Property Definition
Select the attribute that you wish to plot, or click the advanced button
Video Tutorials
Category:
General properties
Advanced...
Attribute:
<None>
<None>
Date first used
Density
Price
Axis Settings

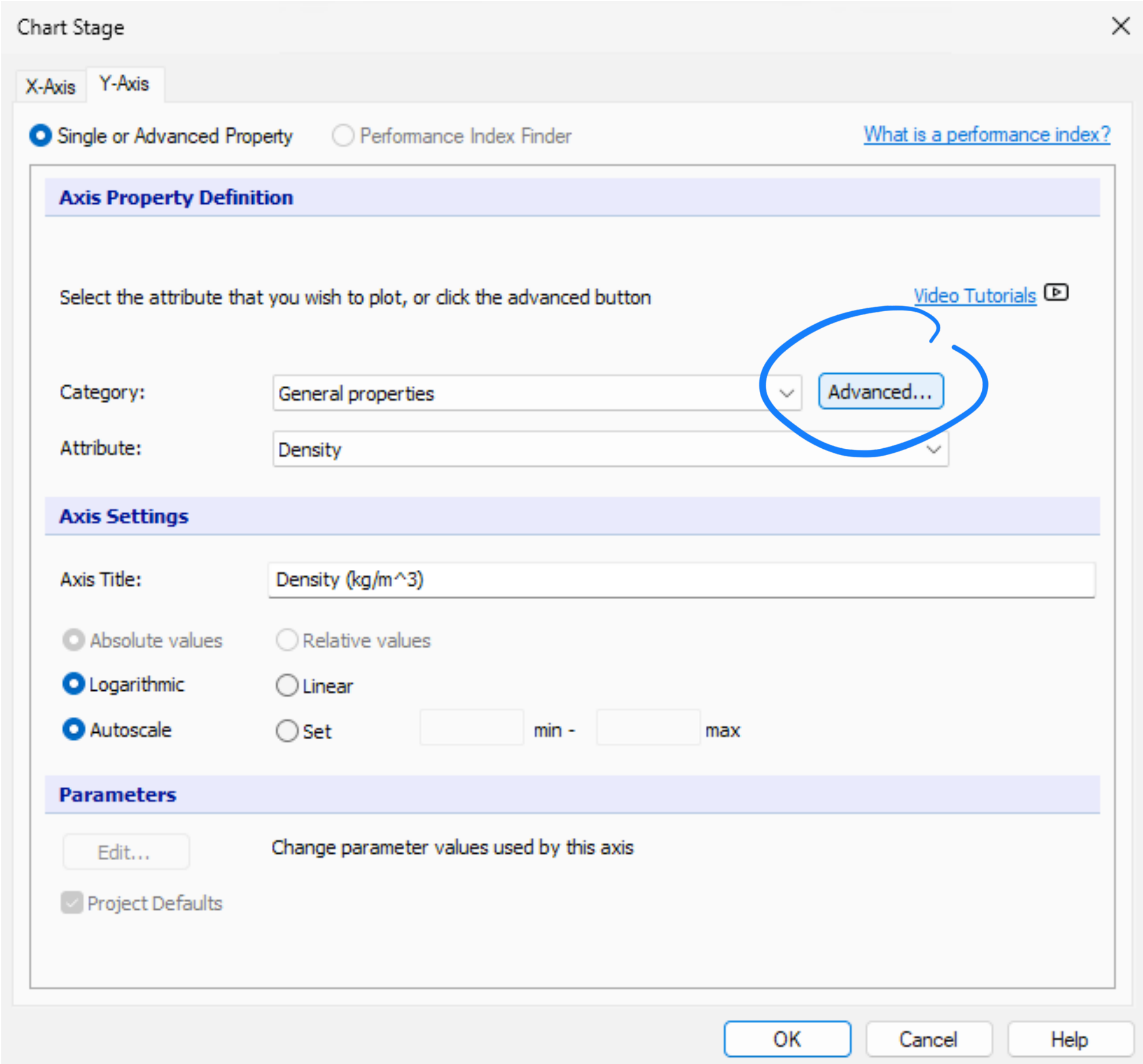
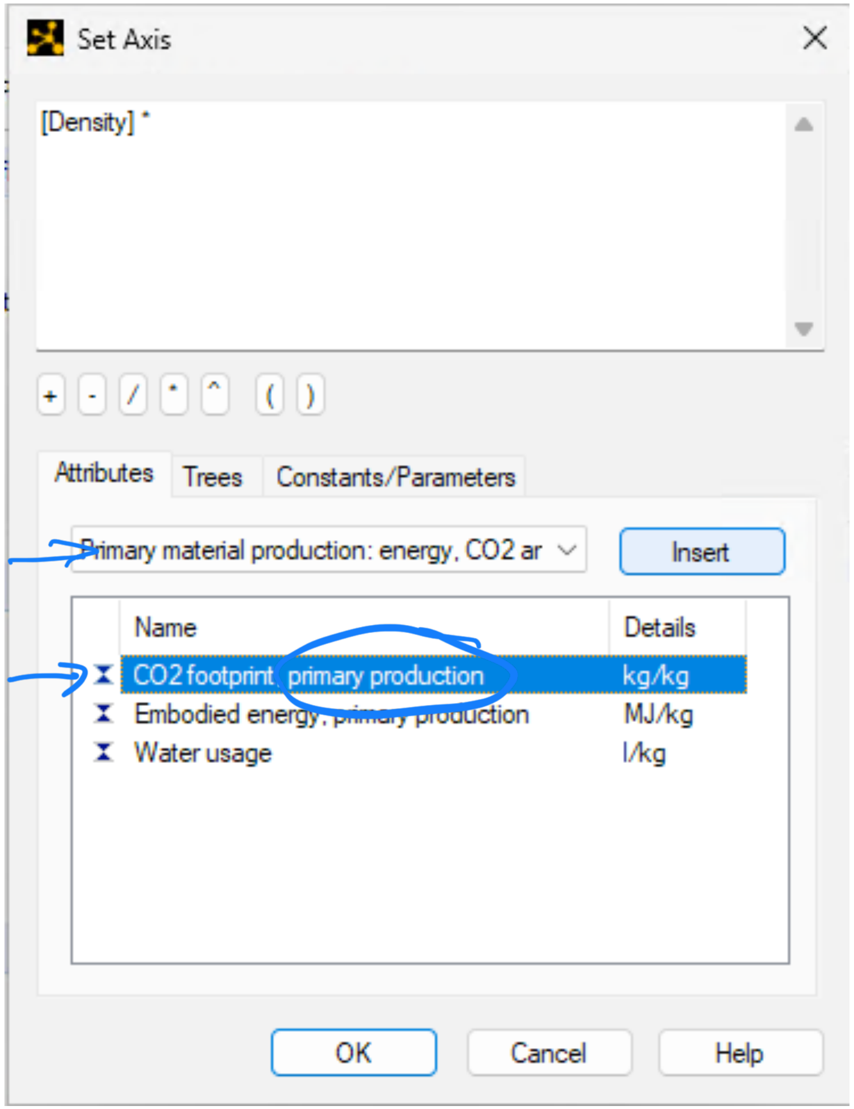


Chart Stage
X-Axis
Y-Axis
Single or Advanced Property
Performance Index Finder
What is a performance index?
Axis Property Definition
Select the attribute that you wish to plot, or click the advanced button
Video Tutorials
Category:
General properties
Advanced...
Attribute:
Density
Axis Settings
Axis Title:
Density (kg/m^3)
Absolute values
Relative values
Logarithmic
Linear
Autoscale
Set
min -
max
Parameters
Edit...
Change parameter values used by this axis
Project Defaults
OK
Cancel
Help



Set Axis
[Density] *
+
-
/
*
^
(
)
Attributes
Trees
Constants/Parameters
Primary material production: energy, CO2 ar
Insert
Name
Details
CO2 footprint, primary production
kg/kg
Embodied energy, primary production
MJ/kg
Water usage
l/kg
OK
Cancel
Help

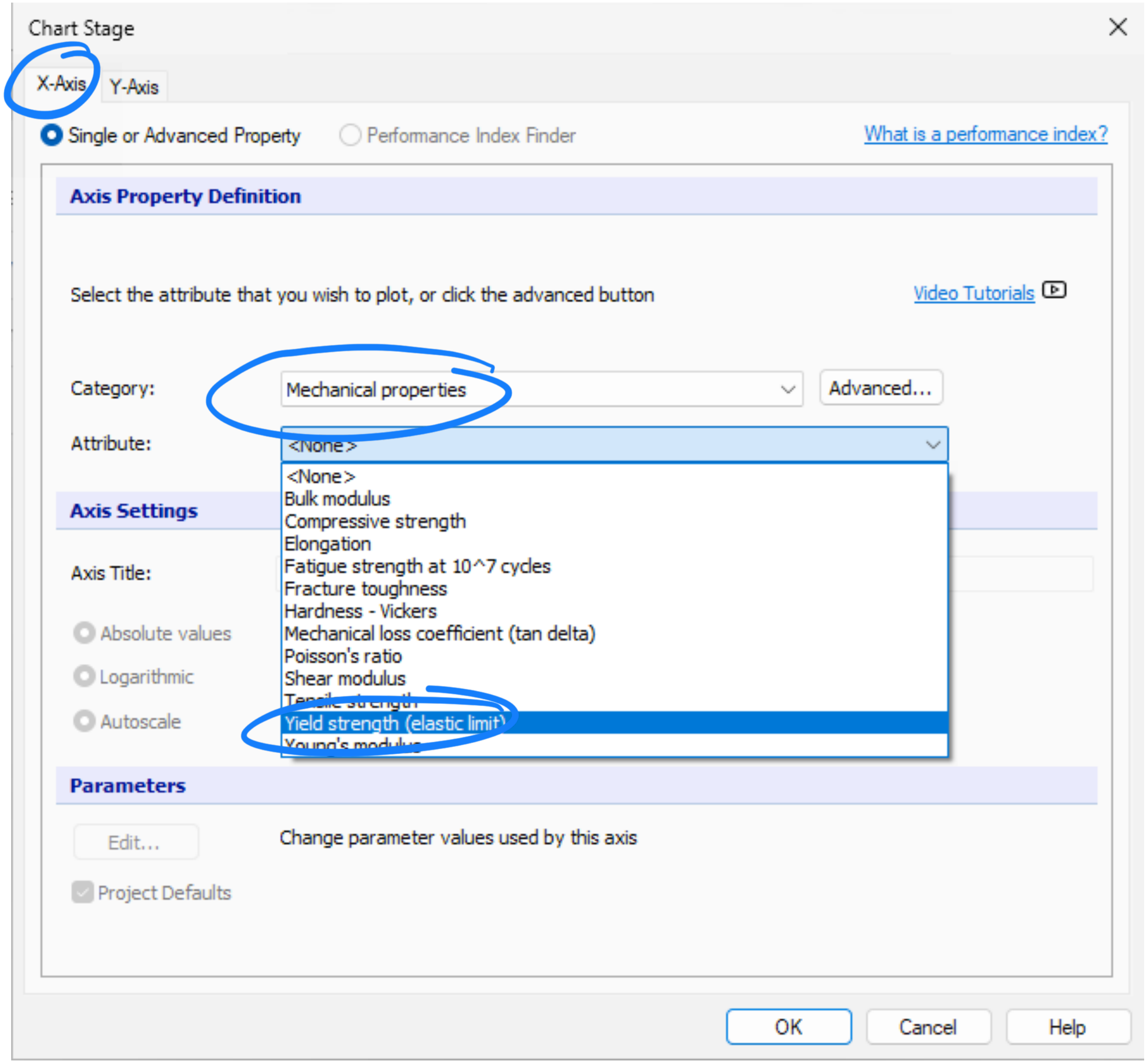
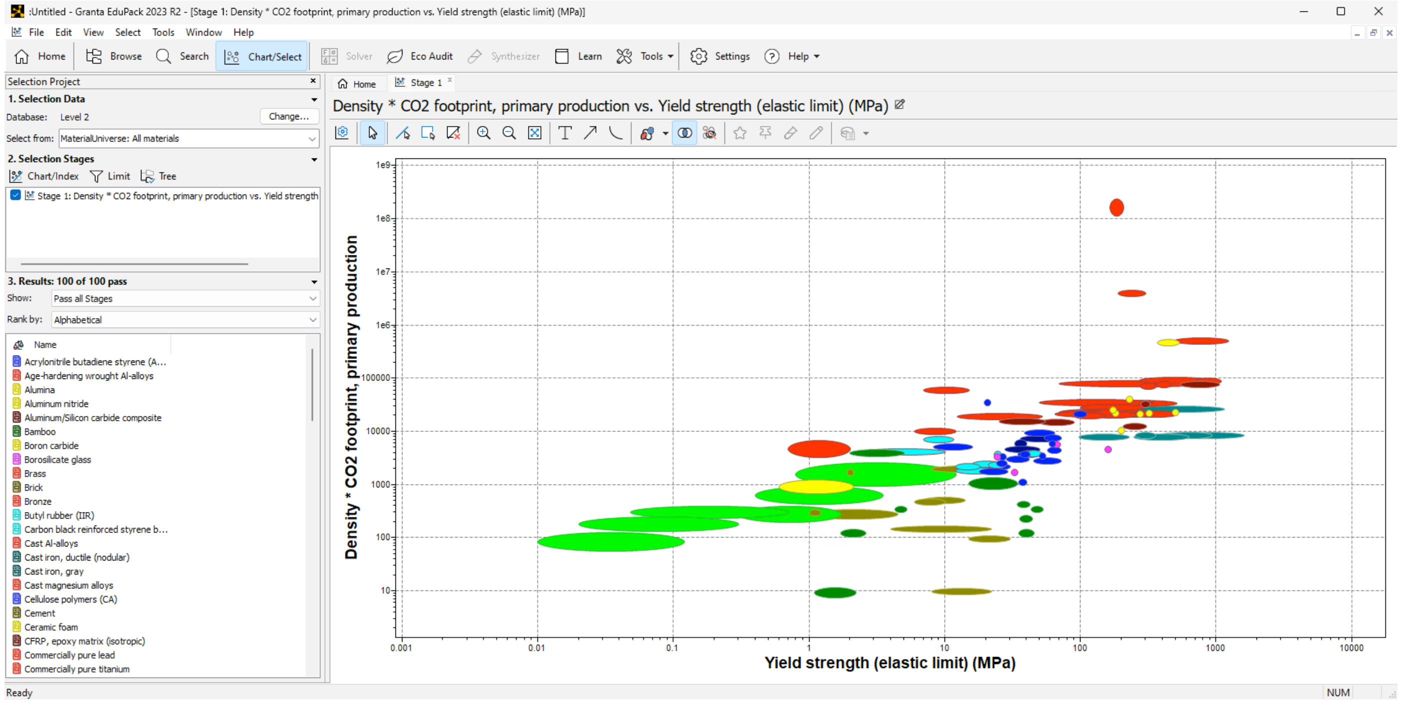
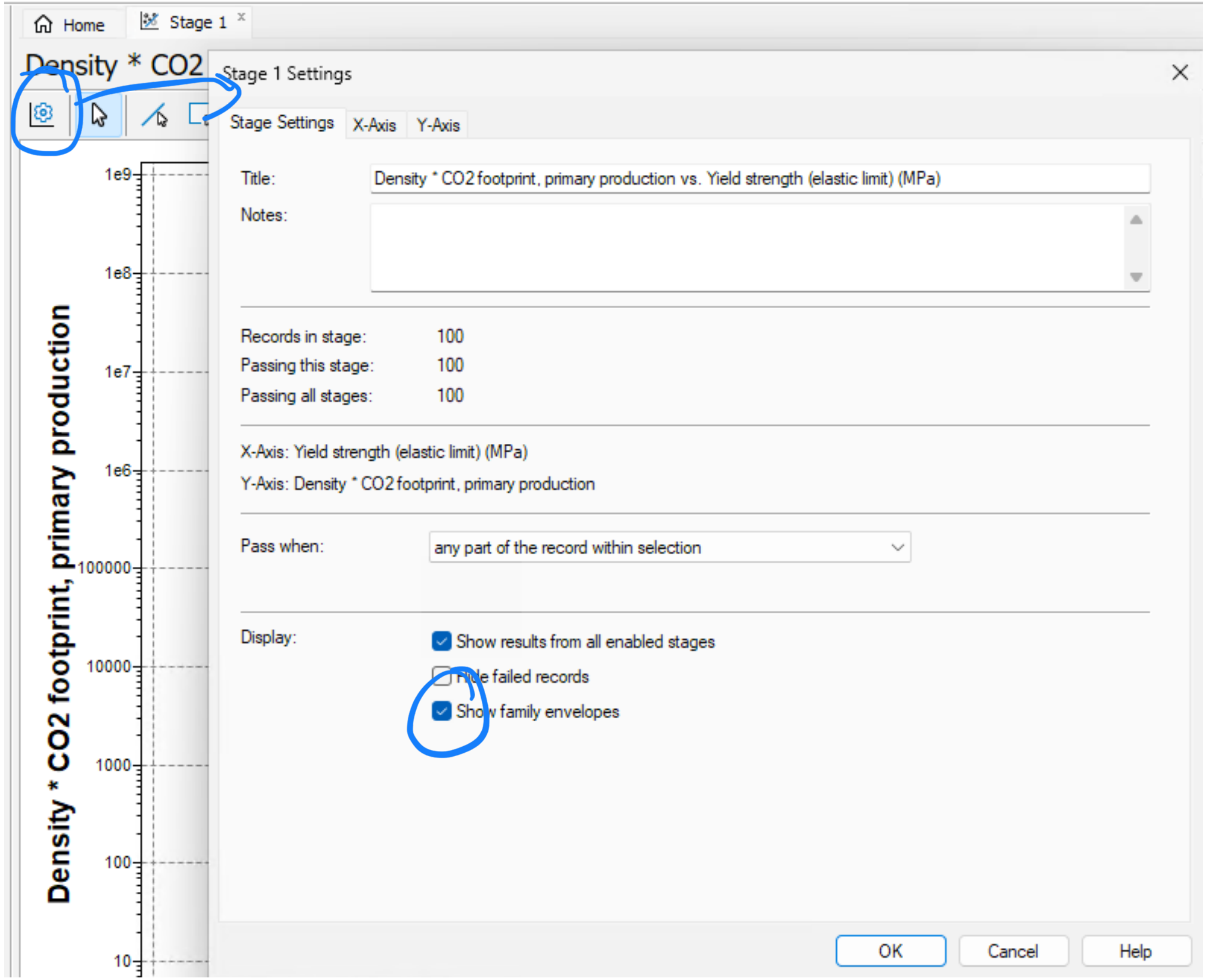
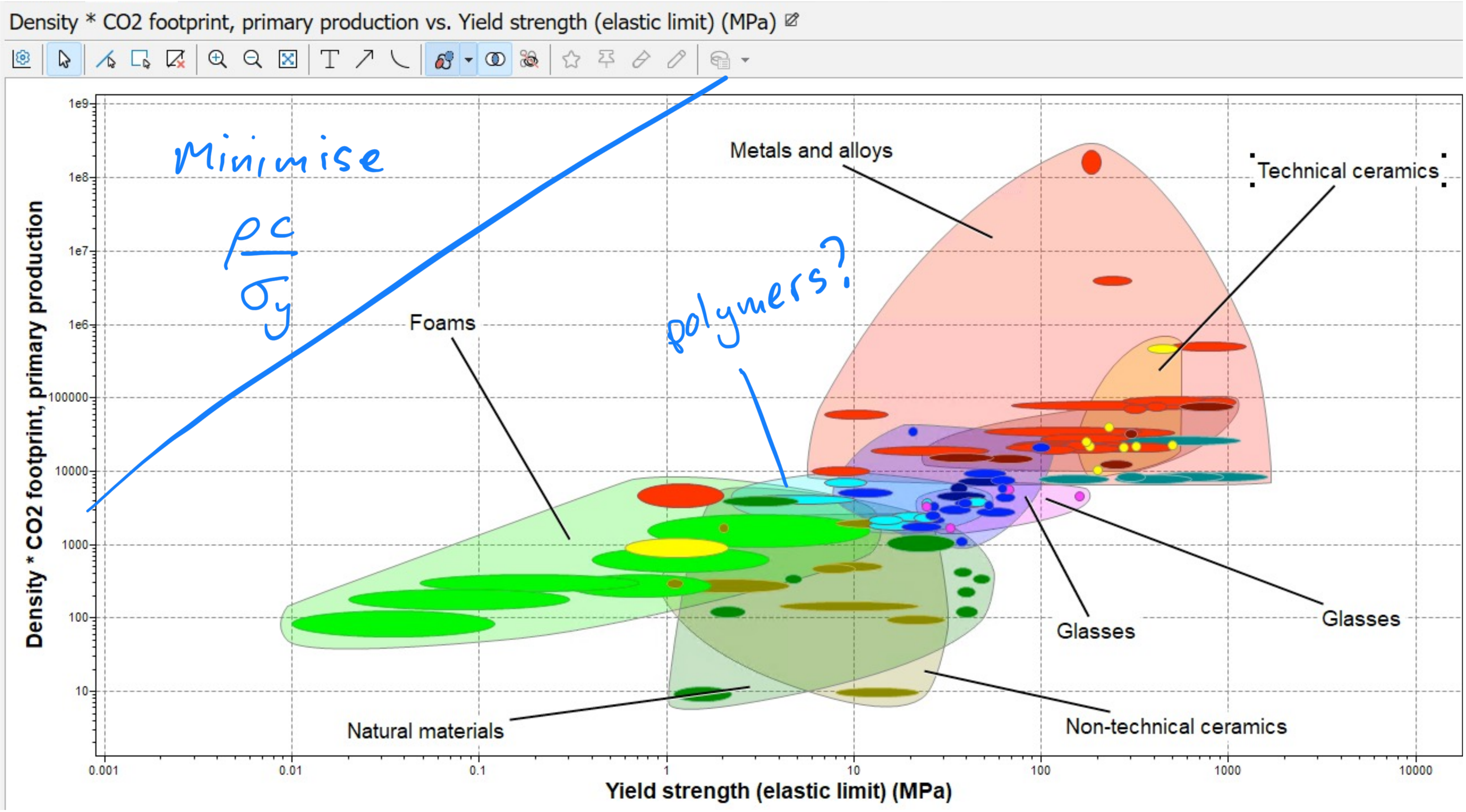
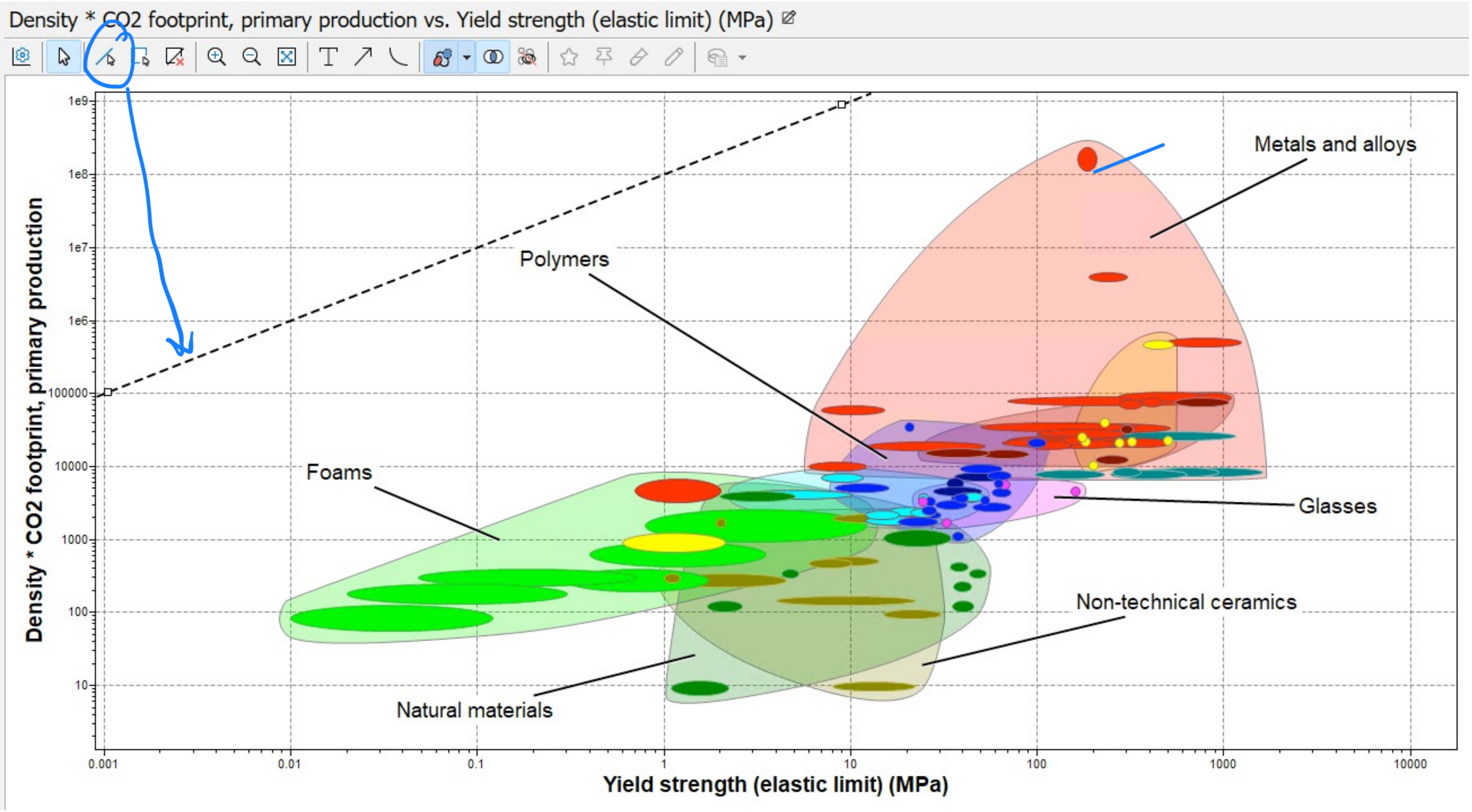


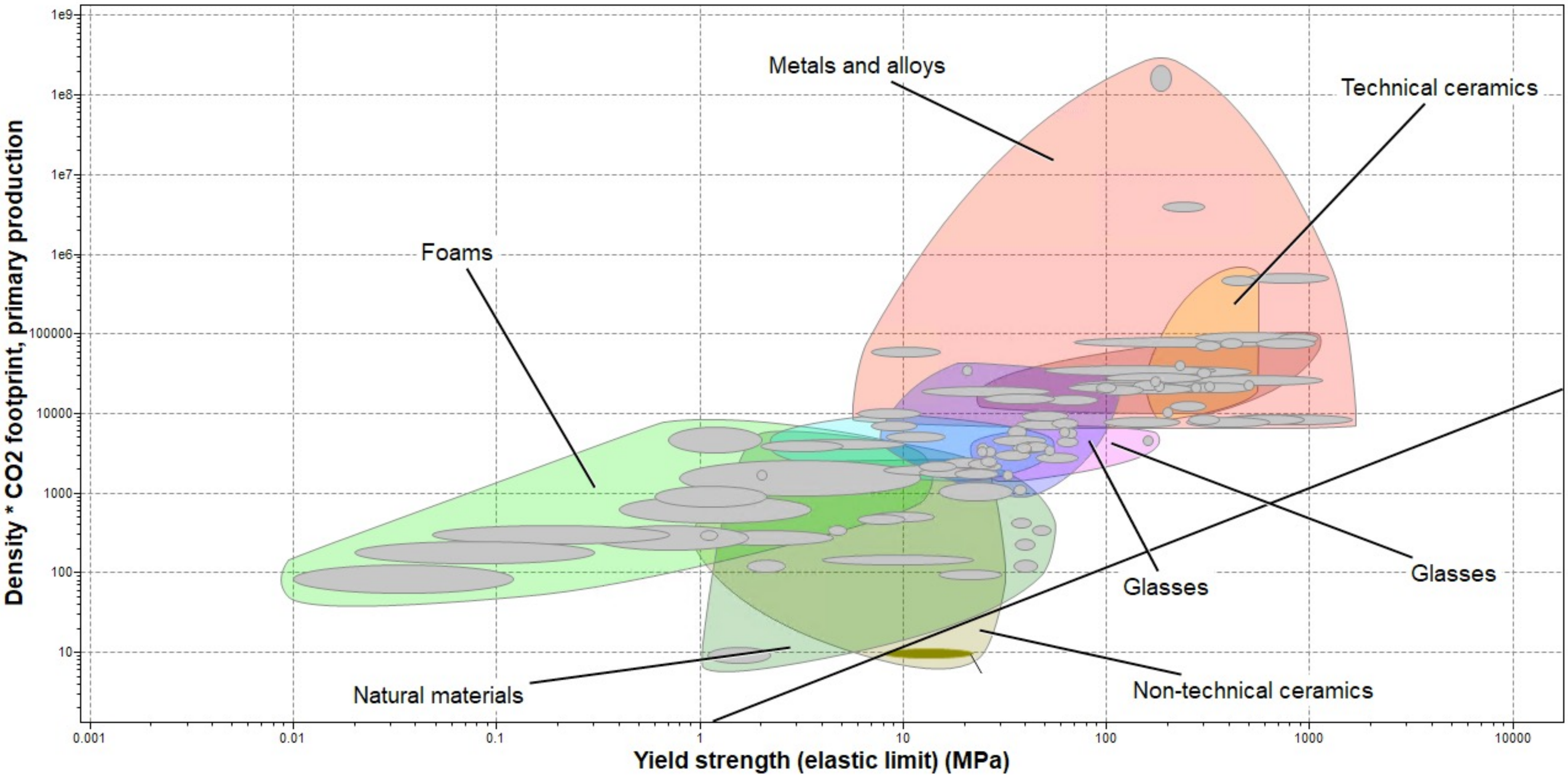
Chart Stage
X-Axis
Y-Axis
Single or Advanced Property
Performance Index Finder
What is a performance index?
Axis Property Definition
Select the attribute that you wish to plot, or click the advanced button
Video Tutorials
Category:
Mechanical properties
Advanced...
Attribute:
<None>
<None>
Bulk modulus
Compressive strength
Elongation
Fatigue strength at 10^7 cycles
Fracture toughness
Hardness - Vickers
Mechanical loss coefficient (tan delta)
Poisson's ratio
Shear modulus
Tensile strength
Yield strength (elastic limit)
Young's modulus
Axis Settings
Axis Title:
Absolute values
Logarithmic
Autoscale
Parameters
Edit...
Change parameter values used by this axis
Project Defaults
OK
Cancel
Help


:Untitled - Granta EduPack 2023 R2 - [Stage 1: Density * CO2 footprint, primary production vs. Yield strength (elastic limit) (MPa)]
File Edit View Select Tools Window Help
Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help
Selection Project
1. Selection Data
Database: Level 2
Change...
Select from: MaterialUniverse: All materials
2. Selection Stages
Chart/Index Limit Tree
Stage 1: Density * CO2 footprint, primary production vs. Yield strength
3. Results: 100 of 100 pass
Show: Pass all Stages
Rank by: Alphabetical
Name
Acrylonitrile butadiene styrene (A...
Age-hardening wrought Al-alloys
Alumina
Aluminum nitride
Aluminum/Silicon carbide composite
Bamboo
Boron carbide
Borosilicate glass
Brass
Brick
Bronze
Butyl rubber (IIR)
Carbon black reinforced styrene b...
Cast Al-alloys
Cast iron, ductile (nodular)
Cast iron, gray
Cast magnesium alloys
Cellulose polymers (CA)
Cement
Ceramic foam
CFRP, epoxy matrix (isotropic)
Commercially pure lead
Commercially pure titanium
Home
Stage 1
Density * CO2 footprint, primary production vs. Yield strength (elastic limit) (MPa)
Density * CO2 footprint, primary production
1e9
1e8
1e7
1e6
100000
10000
1000
100
10
0.001
0.01
0.1
1
10
100
1000
10000
Yield strength (elastic limit) (MPa)
Ready
NUM

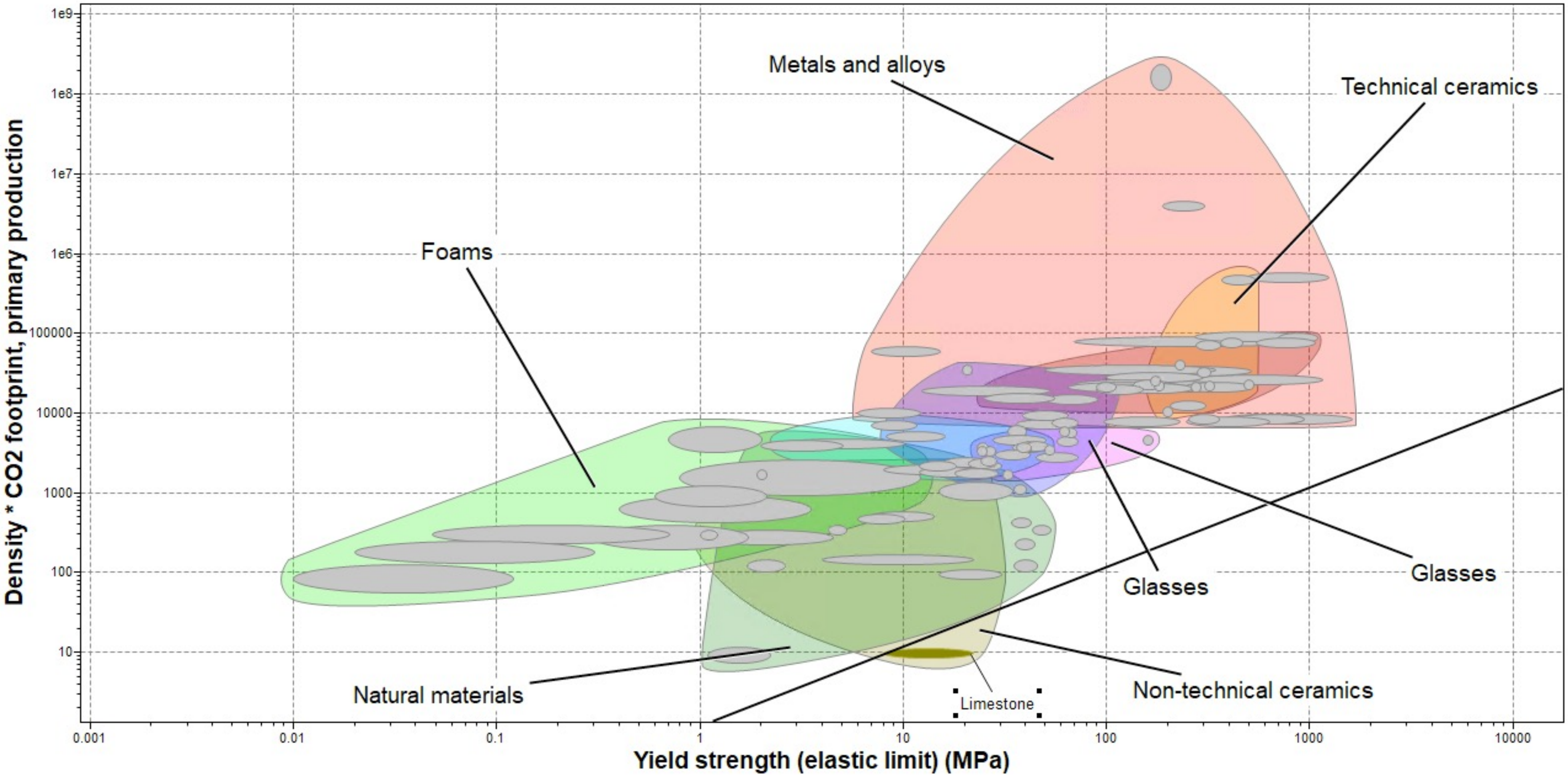

Home
Stage 1
Density * CO2
Stage 1 Settings
Stage Settings
X-Axis
Y-Axis
Title:
Density * CO2 footprint, primary production vs. Yield strength (elastic limit) (MPa)
Notes:
Records in stage: 100
Passing this stage: 100
Passing all stages: 100
X-Axis: Yield strength (elastic limit) (MPa)
Y-Axis: Density * CO2 footprint, primary production
Pass when:
any part of the record within selection
Display:
Show results from all enabled stages
Hide failed records
Show family envelopes
OK
Cancel
Help
Density * CO2 footprint, primary production
1e9
1e8
1e7
1e6
100000
10000
1000
100
10


Density * CO2 footprint, primary production vs. Yield strength (elastic limit) (MPa)
Minimise
$\frac{\rho c}{\sigma_y}$
polymers?
Metals and alloys
Technical ceramics
Foams
Glasses
Glasses
Natural materials
Non-technical ceramics
Density * CO2 footprint, primary production
Yield strength (elastic limit) (MPa)
1e9
1e8
1e7
1e6
100000
10000
1000
100
10
0.001
0.01
0.1
1
10
100
1000
10000


Density * CO2 footprint, primary production vs. Yield strength (elastic limit) (MPa)
Metals and alloys
Polymers
Foams
Glasses
Non-technical ceramics
Natural materials
Density * CO2 footprint, primary production
1e9
1e8
1e7
1e6
100000
10000
1000
100
10
0.001
0.01
0.1
1
10
100
1000
10000
Yield strength (elastic limit) (MPa)



Metals and alloys
Technical ceramics
Foams
Glasses
Glasses
Natural materials
Non-technical ceramics
Density * CO2 footprint, primary production
Yield strength (elastic limit) (MPa)
1e9
1e8
1e7
1e6
100000
10000
1000
100
10
0.001
0.01
0.1
1
10
100
1000
10000



Metals and alloys
Technical ceramics
Foams
Glasses
Glasses
Natural materials
Non-technical ceramics
Limestone
1e9
1e8
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1e6
100000
10000
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Density * CO2 footprint, primary production
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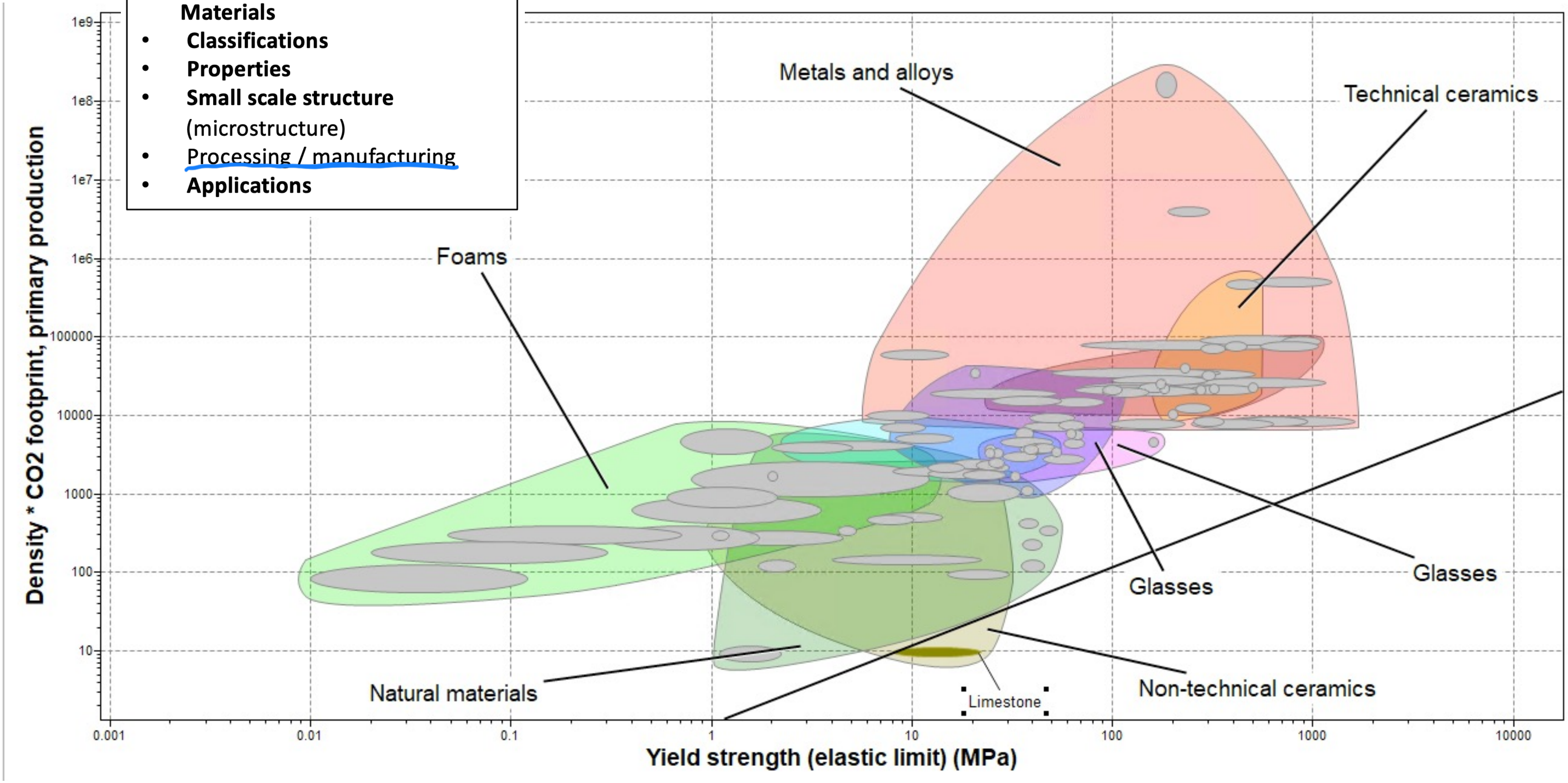
WHAT Framework

Materials

- **Classifications**
- **Properties**
- **Small scale structure** (microstructure)
- Processing / manufacturing
- **Applications**



WHAT Framework

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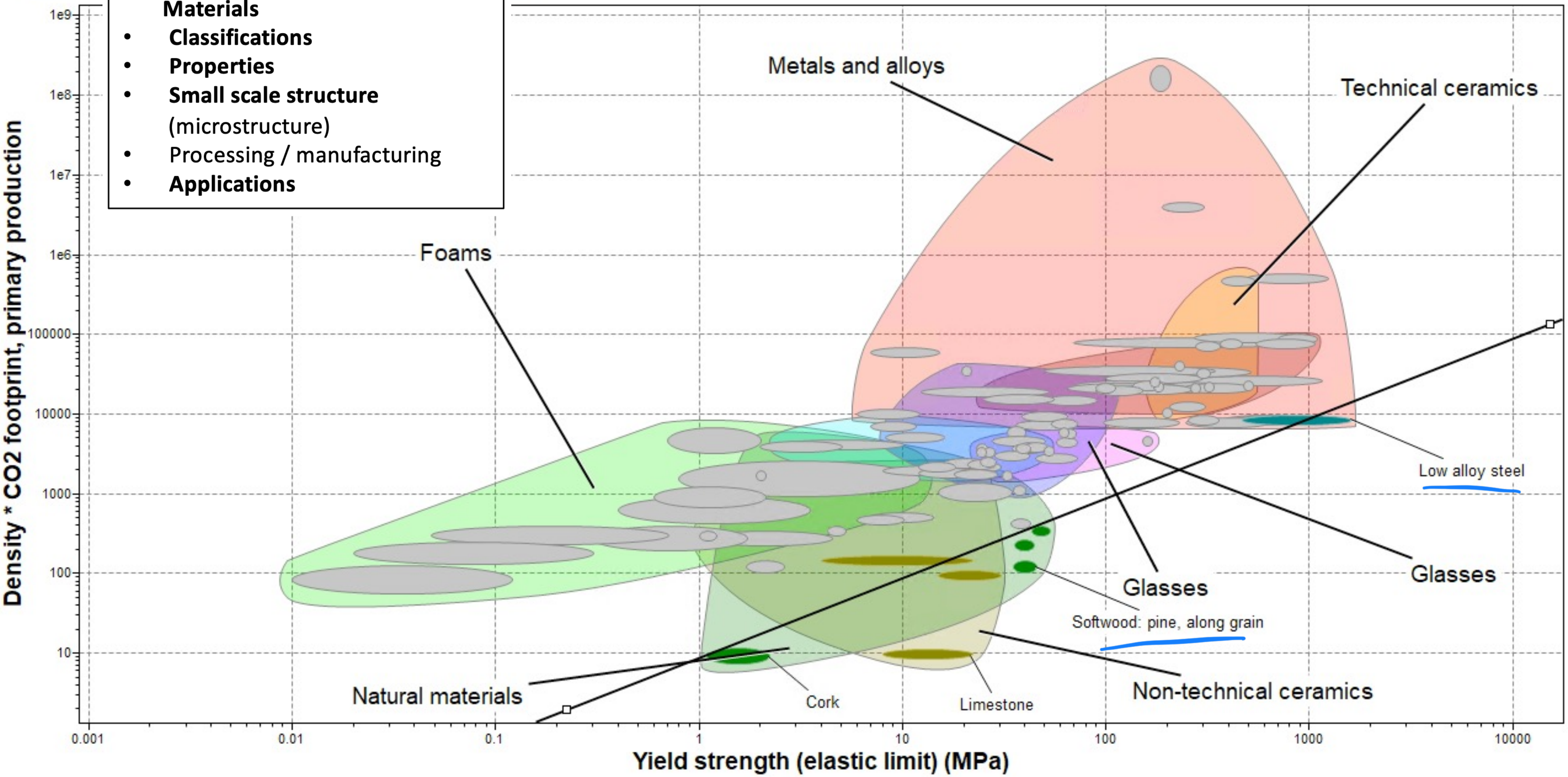


Defining the problem: what properties matter?

Defining the problem: what properties matter?

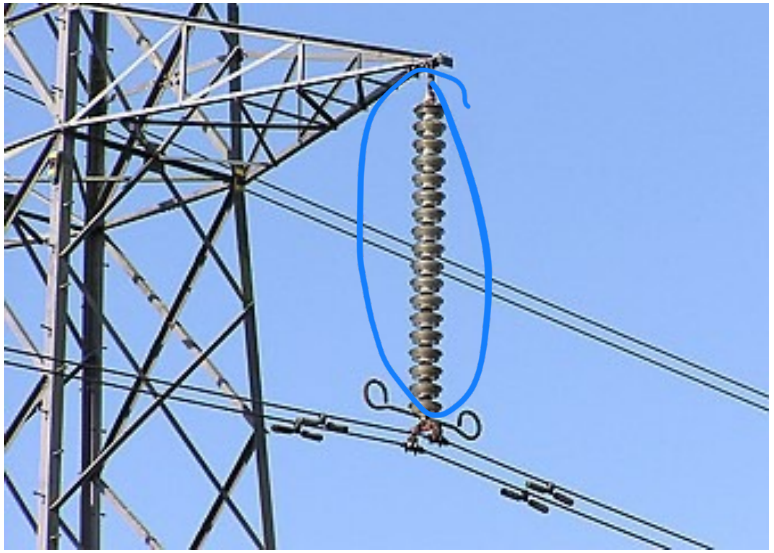
Connection between high voltage lines and pylon structure

(Insulator string)

low conductivity

durability

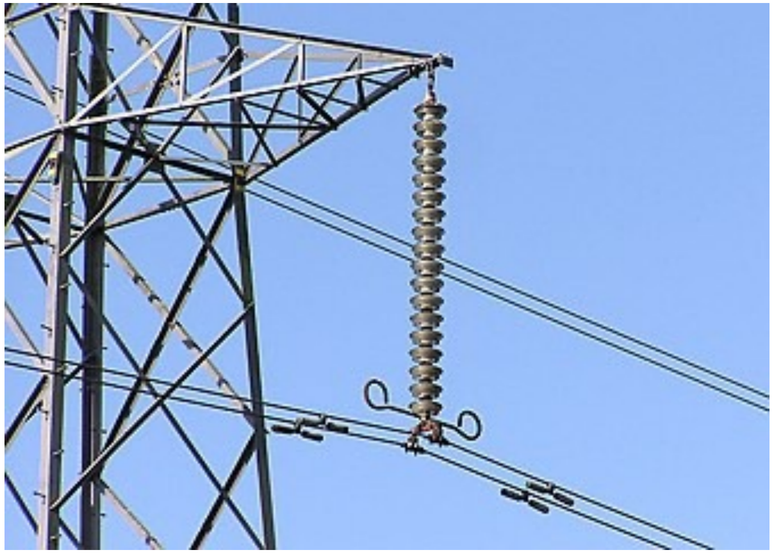
thermal



Defining the problem: what properties matter?

Connection between high voltage lines and pylon structure

- Electrical conductivity
- Strength
- Elastic modulus
- Durability
- Operating temperature
- Embodied carbon
- Cost



Defining the problem: what properties matter?

Thermal insulation for buildings

Cost
Health hazard
Fire resistance
thermal conductivity

Defining the problem: what properties matter?

Thermal insulation for buildings

- Thermal conductivity
- Moisture sensitivity
- Compressive strength
- Ease of installation
- Durability

…

Defining the problem: what properties matter?

Thermal insulation for buildings

...

- Toxicity
- Flammability
- Embodied carbon