Autodesk Inventor Eco-Materials Adviser®
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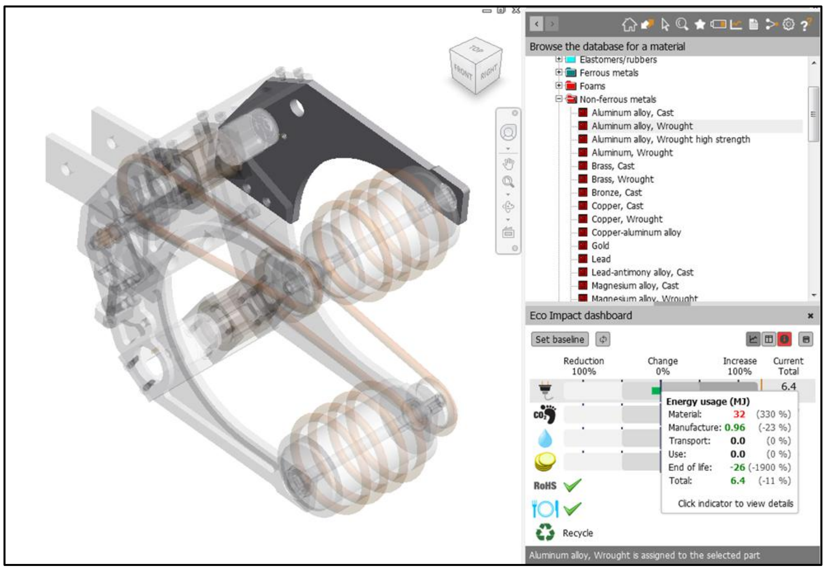
Eco-Materials Adviser – Recommended Workflow for Students



This is a manual to support the use of the Autodesk® Inventor® Eco Materials Adviser on design projects. The Eco Materials Adviser provides quick and practical guidance on material selection in the early stages of design. The tool evaluates environmental impacts including energy usage, CO_2 footprint, water use, and cost. This enables exploration of alternatives and provides a rational basis for material choices.

Contents

Introduction

The Eco Materials Adviser was developed in partnership with Granta Design, who specializes in materials information technology. This add-in allows engineers to access more detailed data about the environmental attributes, technical performance, and cost of the materials within Inventor.

The default, free install includes information on 53 materials that are part of Inventor's material library (see a list in Appendix A). For the full Material Universe of 3,500 materials, the full, paid version is required.

Why use the Eco Materials Adviser

Throughout the design process, an engineer must make quick, yet calculated choices that will affect all aspects of the product's life, from manufacturing to end usage. A common decision during this design process is selecting materials. An optimal material will meet design constraints and requirements that consider factors like cost, strength, weight and minimal environmental impact.

Finding materials that are environmentally or technically preferable can require extensive research. The Eco Materials Adviser helps you access good materials and process data to make more informed choices.

The most appropriate strategy for improving the environmental impact of your design depends on your product and how it's used. Some tips to find the right strategy are in Appendix B.

Additional Resources

- **Sustainability Workshop on materials selection** – This will always be updated with the latest educational materials.
- **Eco Materials Adviser User's Guide from Granta Design -** This site explains the user interface and functionality of the Eco Materials Adviser tool. It also contains other product information and software updates.
- **Autodesk Inventor Wiki-Help** - Learn the basic procedures needed to use the tool, and share your knowledge and insights on this wiki platform.
- **Whitepaper by Granta Design: The Five Steps to Eco-Design** (available from Granta's website) This short booklet provides advice on how you can tackle environmental issues within product design in an integrated and cost-effective manner. It is not specific to the tool, but helps provide context for Granta's eco design philosophy. Download the PDF to learn more about these core tips.
  Consider environmental impact early in the design process
  1. Consider environmental impact early in the design process
  2. Imprecise data can guide good decisions
  3. Consider the entire product system
  4. Materials and process decisions are critical to environmental impact and eco design
  5. Establish targets and the information systems to support them

Eco Materials Adviser Workflow Overview

Step 1: Establish design requirements and environmental priorities. Review the requirements of your design, such as strength, weight and cost. Think of potential ways your product will be manufactured, used and disposed of to understand environmental priorities.

Step 2: Set baseline materials and processes. Set a baseline for your design's materials and processes. Calculate baseline numbers to see which components, materials, or processes are contributing the most embodied energy.

Step 3: Search for alternatives. Search for material alternatives based upon your design requirements, goals, and baseline materials. Reference the material datasheets.

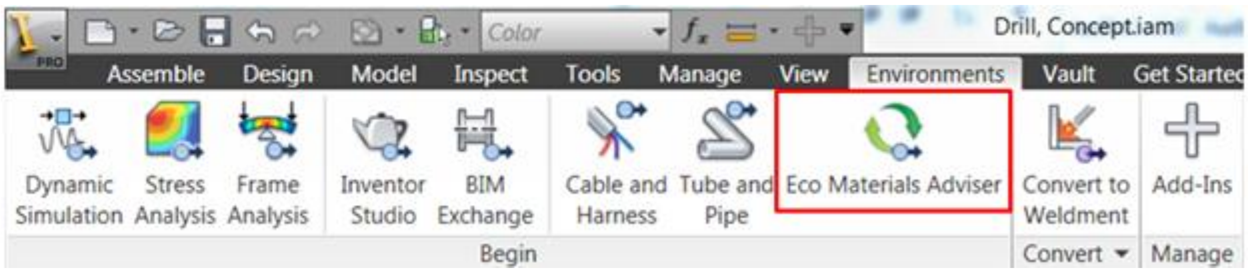
Step 4: Weigh trade-offs of alternative materials and processes. Apply alternate materials to your design. Run the analysis to compare results vs. the baseline.

Step 5: Make and document the material choice. Make all your final material assignments, embed data from the Eco Materials Adviser into iProperties, and create other reports/ documentation as needed. Ensure that you've made any design changes needed based on any new materials and processes.

Navigating the UI

For more information on the UI and specific features, see Autodesk WikiHelp.

The Eco Materials Adviser can be found in the "Environments" tab found on the user interface-ribbon in Autodesk Inventor 2012. If Eco Materials Adviser is not showing up in your Environments tab, see the troubleshooting instructions in Appendix D.



Toolbar

The **toolbar** provides access to the main functions and tasks. Hover over an icon to see the function name.

Home - returns to the Eco Materials Adviser homepage

View and edit assignments - shows the materials and processes currently assigned to each part, and allows you to assign new materials and processes

Browse - shows a tree view of your Eco Materials Adviser database, and allows you to browse for materials

Search - allows you to search for materials by name, or by material or environmental properties

Manage your favorites - allows you to view and edit a list of favorite materials

View dashboards - shows the results of an eco-impact analysis of your current design, in a visual format

View reports - allows you to view and print a PDF report of your analysis

Settings - allows you to choose your preferred currency and unit system, and see your database settings

Help - opens the User Guide in a browser window

NOTE: The full version also includes toolbar icons for the use phase and transport phases, and to help map materials.

Eco Impact Dashboard

The Eco Impact Dashboard is accessible with the "**Analyze**" or "View Dashboard" button.

The Eco Impact dashboard shows the embodied energy, carbon footprint, water and cost of our design. A check mark occurs when the material selected will pass the RoHS standard or if it is FDA approved to be used for food handling. Last but not least, the recycle icon will tell us how the product should be disposed of.

Baseline – sets the currently selected material and process as the standard or baseline material. This information will then be what future materials are compared to.

Refresh – updates the eco impact dashboard to account for new changes.

View Summary – displays a visual summary of the materials and processes selected.

View Details – displays an in-depth eco-analysis of the materials and processes selected.

Information – shows information if the analysis is incomplete. Will be displayed red if something can be changed to improve analysis.

Save Analysis Results – saves analysis results to the component, which shows up as "custom" data in iProperties.

Energy Usage – displays the embodied energy in mega-Joules (MJ) of the materials and processes for your part or assembly (embodied energy, energy to manufacture and energy required in end of material life).

Carbon Footprint – displays the amount of embodied carbon dioxide (in kilograms) of the materials and processes being analyzed in your design .

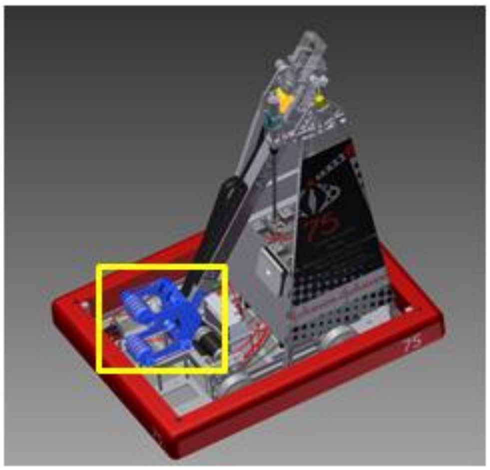
Water Usage – displays the water used (in liters) for materials and processes being analyzed in your design.

Cost – displays the material cost in USD of a specified part or assembly.

Compliance – displays if the material will pass the RoHS standard, FDA's standard for food contact and a recommended method of disposal at the end of the product's life.

Recommended Workflow

The following example is based on a design from the [FIRST Robotics Competition.](#) Students design and assemble a robot to navigate an arena to complete various tasks. The "RoboRaiders" robot from Hillsborough High competed in 2011. For our example, we'll analyze the gripper (end effector assembly), as highlighted in the pictures below. Let's attempt to reduce this end effector design's impact on the environment, while maintaining the design criteria needed to compete.



STEP 1: Establish Design Requirements and Environmental Priorities

Establishing Design Constraints

The end-effector assembly design has to be lightweight in order to quickly engage the game piece, as well as strong and durable enough to withstand potential hits during in game maneuvering. On top of all of this, the robot as a whole must maintain competition criteria such as weight, size and cost.

After performing some initial calculations, let's make the following assumptions for material criteria of a structural component:

- Yield strength – Minimum of 50 MPa
- Young's modulus – Minimum of 2 GPa
- Density – Maximum of 2700 kg/m^3
- Price – Maximum of $5.00/kg

TIP! Use the material properties of a material you're familiar with to help set these baseline constraints.

TIP! To use the data built-into the Eco-Materials Adviser, you need to have some geometry in Autodesk Inventor. To investigate materials before you've done any CAD modeling, just extrude a square or a cylinder that you can apply an initial material to.

Establishing Environmental Goals

Deciding which environmental goals to focus on depends on the design and how it is used. Some environmental goals related to material choice are:

- Reducing the embodied energy
- Minimizing weight
- Maximizing insulation or heat transfer properties
- Increasing the recyclability
- Ensuring RoHS compliance

For example, reducing the embodied energy of the materials is often most important for designs that don't use energy for use. While lightweighting, or improving heat transfer, might be more important for a design that uses energy. Some other goals, such as increasing the recyclability or ensuring RoHS compliance will usually always want to be achieved. For more specific guidance, see Appendix B.

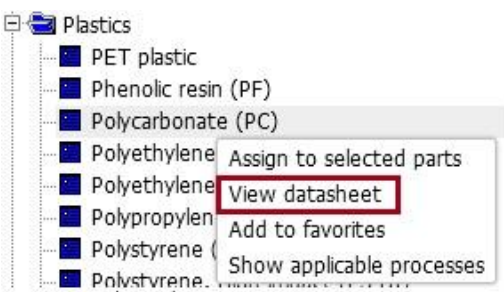
In the full version of the Eco Materials Adviser, you can analyze energy use during your product's use, as well as environmental impacts from distribution. For more on these capabilities within the full version, see Appendix C.

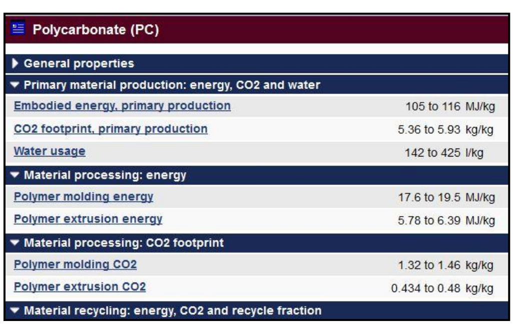
In our specific example of the FIRST robotics robot, we will focus on finding a material with the lowest embodied energy. Our robot will only be used in several competitions in its life, so use phase energy will not be as important.

Exploring the Materials Database

Material datasheets can help set your baseline materials. They include a wealth of information about the material's environmental, mechanical, and thermal properties. They also tell you practical information about the typical uses of the material (i.e. like safety goggles and lenses).

Click on the browse icon to open the Granta Starter Database. We'll start by expanding the plastics category to investigate polycarbonate. Select "View datasheet".





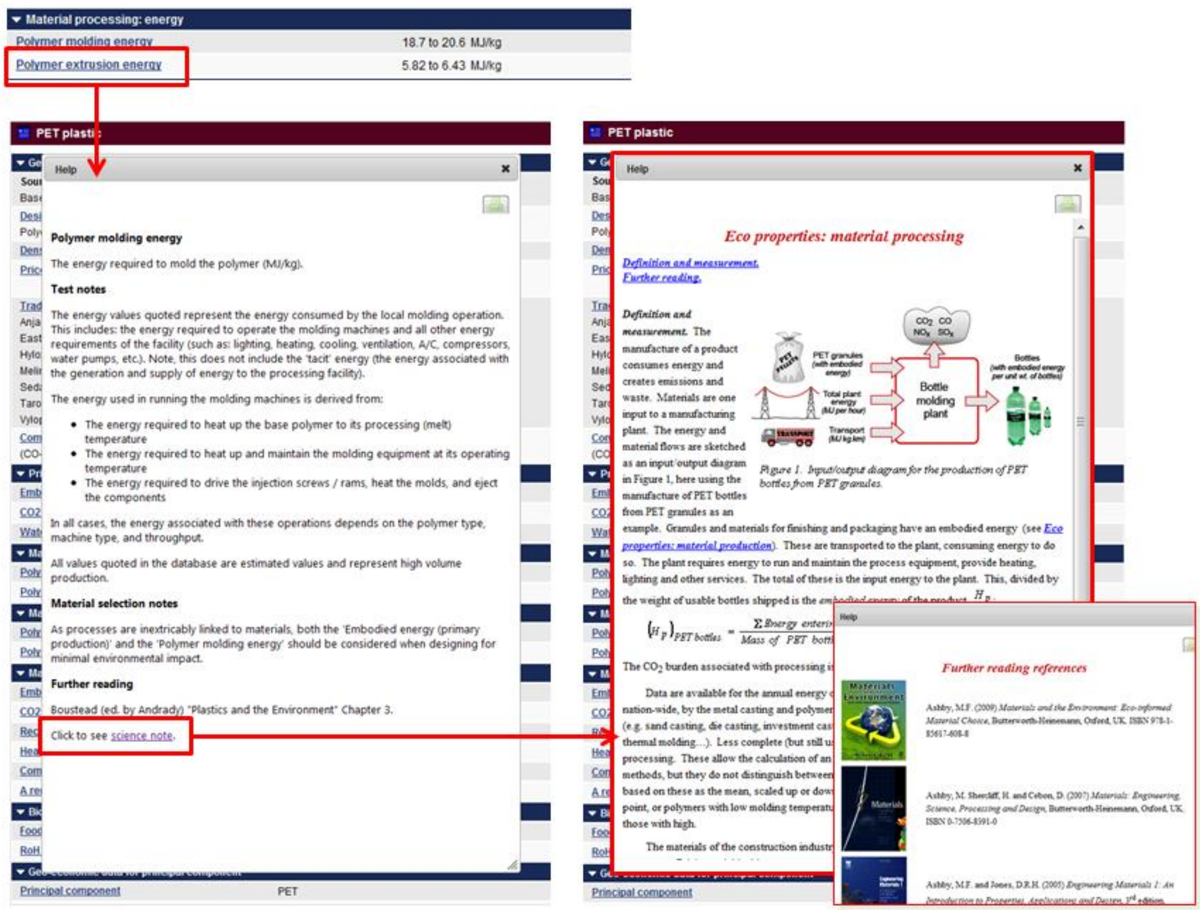
Polycarbonate (PC)	
General properties	
Primary material production: energy, CO2 and water	
Embodied energy, primary production	105 to 116 MJ/kg
CO2 footprint, primary production	5.36 to 5.93 kg/kg
Water usage	142 to 425 l/kg
Material processing: energy	
Polymer molding energy	17.6 to 19.5 MJ/kg
Polymer extrusion energy	5.78 to 6.39 MJ/kg
Material processing: CO2 footprint	
Polymer molding CO2	1.32 to 1.46 kg/kg
Polymer extrusion CO2	0.434 to 0.48 kg/kg
Material recycling: energy, CO2 and recycle fraction	

TIP! Make sure to save your file before making any changes in the Eco Material Adviser, in case you want to keep your part's previous materials.

Using Built-In Definitions and Reference Materials

Definitions and references are built in to the Eco Materials Adviser's Database. Click on the hyperlinks and "Science Notes" to access.

In addition to the environmental properties, there are great diagrams, equations, charts, and short explanations on the fundamentals of things like tensile strength, fracture toughness, and fatigue strength. Having a firm grasp of these concepts is extremely useful in any design.



TIP! School help! Much of the information included in the science notes hyperlinks may help you in courses such as Mechanics of Materials, to help you better understand how materials behave.

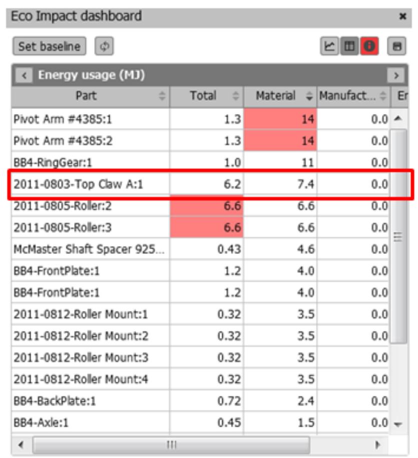
STEP 2: Identify parts to investigate and set a baseline

Identify Parts and Materials to Change

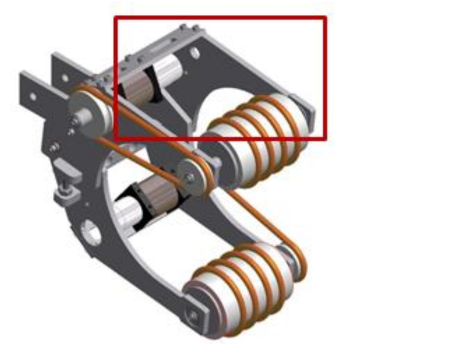
The Eco-Materials Adviser calculates and sums the embodied energy based on the geometry of your assembly. The "View Details" icon - - shows a breakdown of the impacts of each individual part, and highlights the ones with the largest impacts. A few questions to help focus your search for alternative materials:

- **How large are the parts relative to my design?** To make simple and effective changes, look for parts that are the largest or use the most material in your design.
- **Are there many of the same part?** If a part is used in multiple places, its impact can add-up.
- **What parts do you have control over?** Not all materials will be able to be changed easily. Certain parts, like motors, fasteners, and electronics will come pre-fabricated, with limited amount of variation. Use best judgment when selecting these parts.

The Eco Materials Adviser identifies parts with the highest embodied energy. We will single out the end effector's top claw piece, as it is one of the larger components and there are four of them.

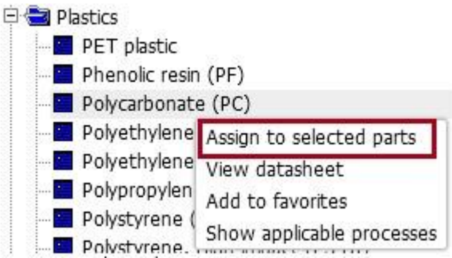

Eco Impact dashboard
Set baseline
Energy usage (MJ)

Part	Total	Material	Manufact...
Pivot Arm #4385:1	1.3	14	0.0
Pivot Arm #4385:2	1.3	14	0.0
BB4-RingGear:1	1.0	11	0.0
2011-0803-Top Claw A:1	6.2	7.4	0.0
2011-0805-Roller:2	6.6	6.6	0.0
2011-0805-Roller:3	6.6	6.6	0.0
McMaster Shaft Spacer 925...	0.43	4.6	0.0
BB4-FrontPlate:1	1.2	4.0	0.0
BB4-FrontPlate:1	1.2	4.0	0.0
2011-0812-Roller Mount:1	0.32	3.5	0.0
2011-0812-Roller Mount:2	0.32	3.5	0.0
2011-0812-Roller Mount:3	0.32	3.5	0.0
2011-0812-Roller Mount:4	0.32	3.5	0.0
BB4-BackPlate:1	0.72	2.4	0.0
BB4-Axle:1	0.45	1.5	0.0



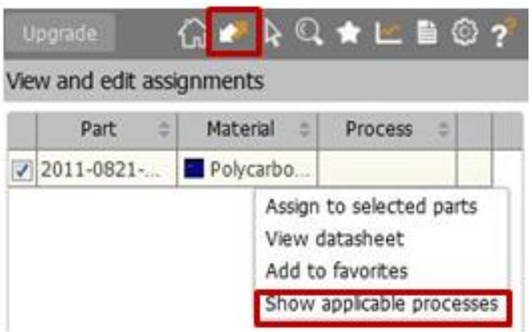
Assigning baseline materials and processes

All of the parts in your model tree are selected by default (up to 20 parts for the base version). To investigate a single part, double click on it.



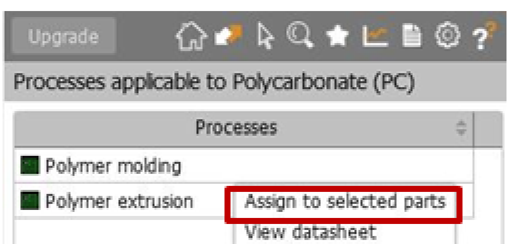
The Eco Materials Adviser will import material assignments created within Inventor's iProperties. In this example, the material and process currently assigned is polycarbonate formed by polymer molding.

But if no material has been assigned, click the browse icon - and find polycarbonate in the plastics section. Click on polycarbonate and then select "Assign to selected parts".

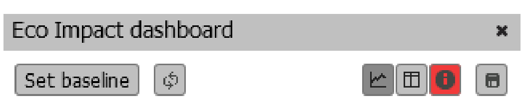


Now indicate how the part will be manufactured, like forging or casting. Manufacturing processes depend on your design's geometry and material.

To change or assign a manufacturing process, click the assign icon at the top of the Eco Materials Adviser, click on the material of the part (Polycarbonate (PC)), and select "Show applicable processes".



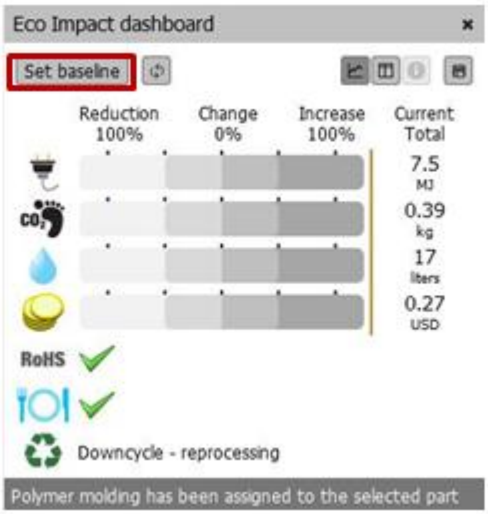
Our two choices are polymer extrusion and polymer molding. We know that our part would be machined from extruded plastic, so we will select this option by clicking on polymer extrusion and selecting "Assign to selected parts".



If you haven't assigned a manufacturing process, the information icon in the Eco Impact Dashboard will be red.

Once we've set the baseline, we can now go to the dashboard to see the impacts.

TIP! **Some manufacturing processes aren't available.** For example, machining is not available in EMA because it would require the user to specify the amount of material removed. Extruding metals (like aluminum) is not included. If this is the case, choose the process that most closely matches. For example, 'Rolling/forging' would be a reasonable approximation for extruding aluminum.



Set the baseline for comparison

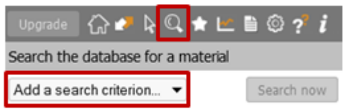
Now let's try and change the material of the end effector's top claw. To compare this material against others, select "Set baseline" on the Eco Impact dashboard.

Now, we have established polymer molded polycarbonate (PC) as our baseline material to **compare** other materials to.

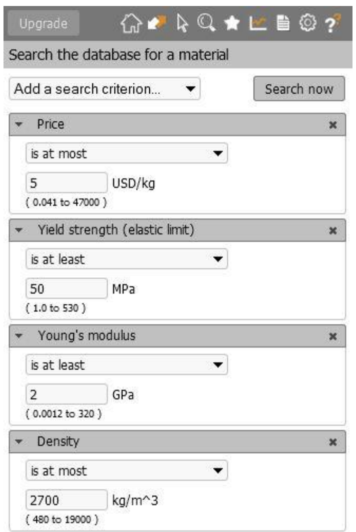
STEP3: Search for alternatives

Search for lower impact materials based upon your design criteria, and substitute materials in your design

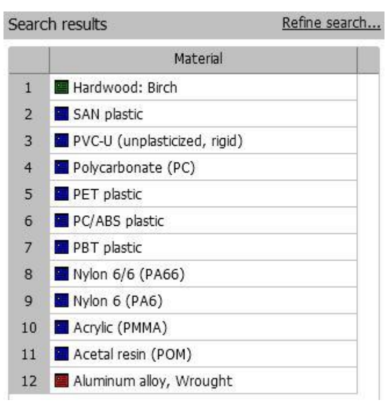
The search function of Eco Materials Adviser allows you to only consider materials that are appropriate for your application.



Based on the design requirements we identified, we can start our search for an alternative material. Select the search icon, and add or modify criterion for the search.



Based on design requirements, we'll add search criteria for Young's Modulus, Yield Strength, density, and cost.



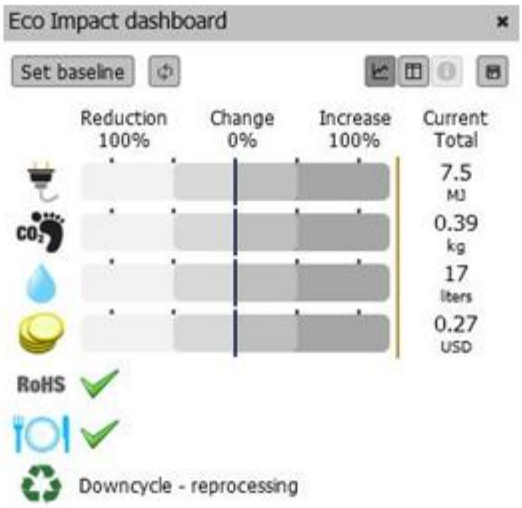
12 materials are found. From here, we can assign these materials to the part to see if they help reduce the environmental impact.

After looking at the choices, we decide to investigate Aluminum Alloy. Aluminum has much stronger mechanical properties that could ensure durability during game play. It also has about double the density, so it will be heavier. But we can machine the aluminum to optimize the part using lightweighting techniques (See Lightweighting on the Sustainability Workshop).

If the environmental impacts aren't too much larger, it will further confirm it as a good alternative to polycarbonate.

STEP 4: Evaluate impacts of alternative materials and weigh the trade-offs.

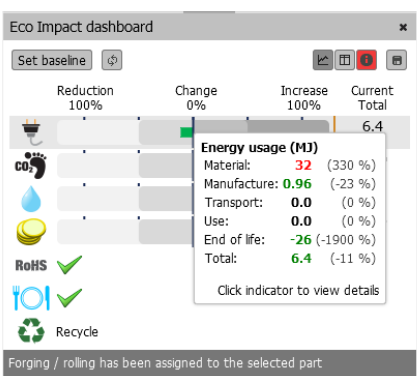
Let's see what happens when we change the material to aluminum alloy, wrought. Select the browse icon at the top. Find and click on aluminum alloy, selecting "Assign to selected parts". Next, select "forging/rolling" as the manufacturing process (as an approximation for machining). We can now see the dashboard has been automatically updated as shown. Let's visually compare our initial material of polycarbonate to the new choice of aluminum alloy.



Original material choice of Polycarbonate

Impact dashboard using Aluminum alloy

TIP! **Keep in mind what the totals actually represent.** For this example our embodied energy required to produce the material goes down by 3.6 MJ. To put that into perspective, it takes 3.6 MJ to run an average sized window air conditioner for one hour or a laptop for 15 hours. (1 kWh = 3.6 MJ)



Hover your mouse curser over the different icons to see more details on these impacts over the entire lifecycle. With Aluminum you'll find that there is a large "end of life credit" because it is so commonly recycled and because recycled aluminum avoids the significant impacts of mining bauxite.

Because we'll be able to ensure the robot is recycled, this credit should apply to us.

(Note that the data here is different and from a different analysis using aluminum)

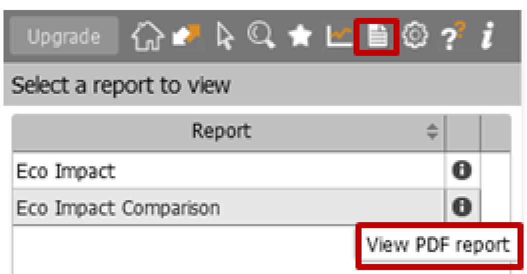
TIP! See the User Guide on Granta's website for an explanation of how these numbers are calculated (end of life strategies, the product lifecycle).

Weighing the Trade-offs

There is no exact answer selecting greener materials, but the final decision can be made by considering at all of the information and comparing it to your environmental goals (see Appendix B). Let's take a look at some of our requirements established in step 1.

- **Density** - Our initial choice of polycarbonate was much lighter than the switch to aluminum, however we can use the strength of aluminum to our benefit and lightweight the now aluminum part. This should help minimize the weight gain from this switch. See step 6 for a visual of the original design compared to the final design.
- **Cost** – Polycarbonate is a less expensive material, but aluminum is still within our budget.
- **Material Strength** – Aluminum is found to be a stronger and more durable material. This is a key advantage, as we want our robot claw to be able to withstand impacts during the game.
- **Embodied energy** – By using aluminum instead of polycarbonate, the embodied energy and carbon have all decreased.
- **Other considerations:**
  - **Water**: The water usage has increased by 160L in the switch from polycarbonate to aluminum; however this might be a trade-off we'll have to make. To put these numbers into perspective – that is about the amount of embodied water in a cup of coffee (140 L) and only 7% of the embodied water in a hamburger (2,400 L).
  - **End of Life:** The recommended action at the end of the design's life as polycarbonate is to downcycle it to a lower grade plastic. In comparison, Aluminum can be more easily recycled, potentially reducing the amount of virgin material required in the market.

After taking this in depth look, it looks like aluminum is a good alternative.



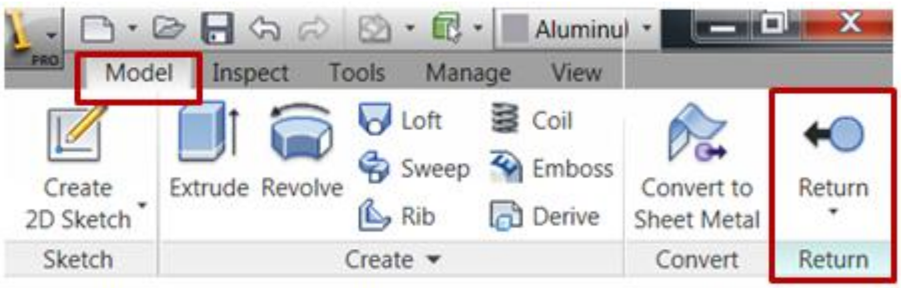
A report can also be generated to display the eco impact of the currently assigned material and process, or a comparison of the current material and baseline material.

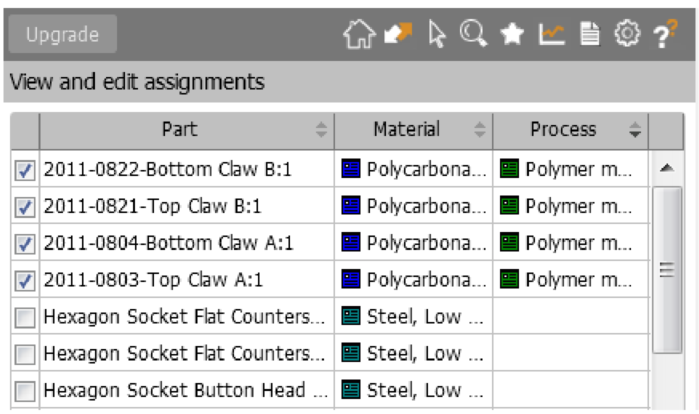
To generate this report, select the reports icon and then click on your choice of report.

TIP! The Eco Impact report gives the 5 highest contributing parts. Reading the report is faster than trying to identify those parts manually by looking at the screen or by calculating their mass or volume.

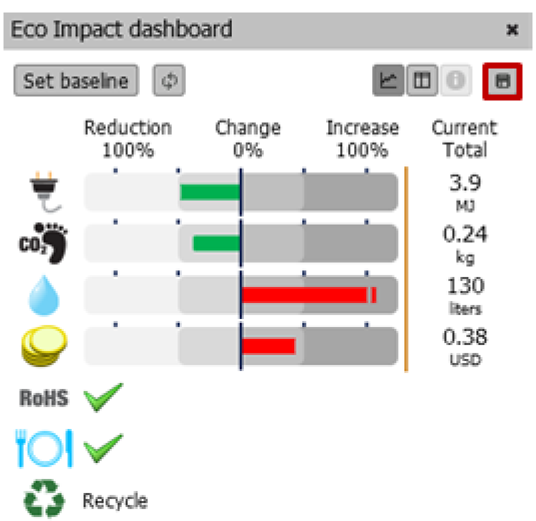
STEP 5: Make and document the material choice

We have decided that aluminum alloy is a better choice for the claw. Let's make this change to the other 3 claws. We can do this by selecting "Return" in the model ribbon.





Next, go to "View and Edit Assignments" - . Select all of the desired parts by holding down the control key on the keyboard while selecting all 4 Claw pieces. A check mark will be displayed if the part is selected. You can assign the material to all four of these parts simultaneously.



Press the "save" icon on the Eco Impact dashboard.

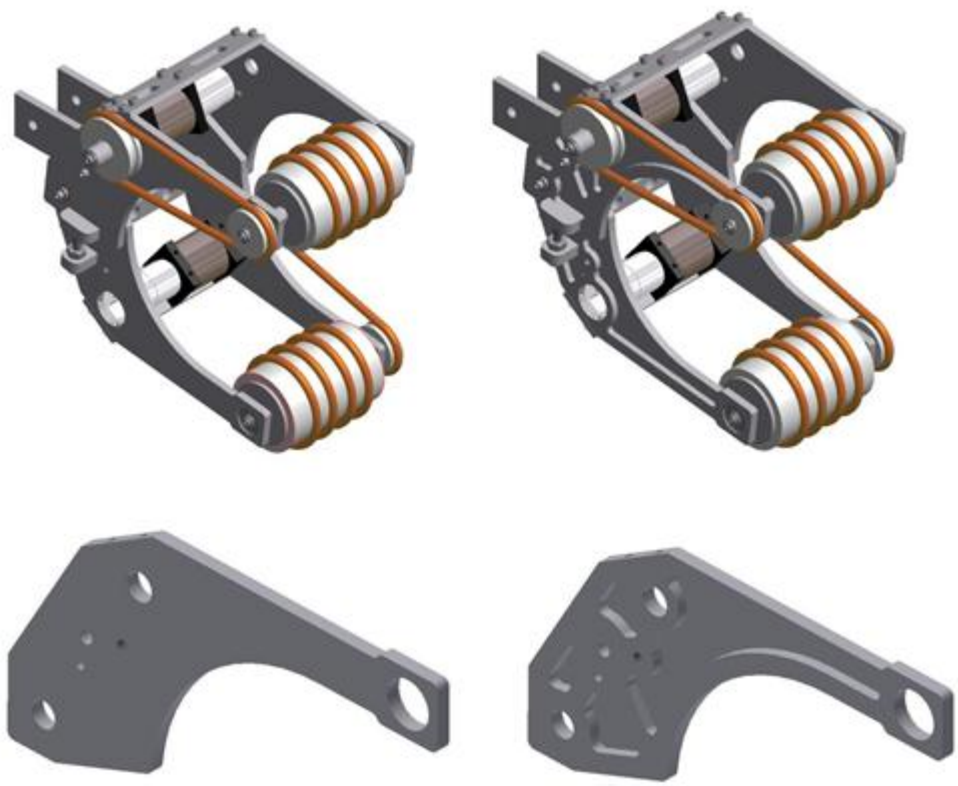
This will save the materials and processes to Inventor's iProperties and update the bill of materials. The same data on Eco Impacts that are shown in the dashboard are also saved to iProperties – allowing you to generate a BOM that includes this information.

You may want to select aluminum as a new baseline and try a few other alternate materials.

Design Geometry

Pay attention to how your material choices impact the process choices and the geometry. When you change the material, the part's geometry may need to be redesigned to account for the change in mechanical properties. All are integrally related.

For example, in switching to aluminum we will be able to remove some of the material in the part, without sacrificing our design requirements for strength. We were able to change the part from a flat piece of polycarbonate to a plate of aluminum with machined-out pockets, as shown below:



Appendix A: Materials Database

The following list contains all of the materials available through the Eco-Materials Adviser

Ceramics and Glass

- Concrete
- Glass
- Silicon nitride

Elastomers/Rubbers

- Natural rubber (NR)
- Silicone rubber (SI)

Ferrous metals

- Cast iron, Ductile
- Cast iron, Gray
- Cast iron, Malleable
- Stainless steel, Austenitic

- Stainless steel, Martensitic
- Steel, Galvanized
- Steel, High strength low alloy (HSLA)
- Steel, Low alloy
- Steel, Low carbon
- Steel, Low carbon (heat treated)

Non-ferrous metals

- Aluminum alloy, Wrought
- Brass, Wrought
- Bronze, Cast
- Copper, Cast
- Copper, Wrought
- Copper-aluminum alloy
- Gold
- Lead
- Nickel-copper alloy
- Silver
- Titanium

Plastics

- ABS plastic
- Acetal resin (POM)
- Acrylic (PMMA)
- LCP Plastic
- Nylon 6 (PA6)
- Nylon 6/6 (PA66)
- PBT plastic
- PC/ABS plastic
- PE-UHMW plastic
- PEEK plastic
- PET Plastic
- Phenolic resin (PF)
- Poly carbonate (PC)
- Polyethylene, High density (PE-HD)
- Polyethylene, Low density (PE-LD)
- Polypropylene (PP)
- Polystyrene, High impact (PS-HI)
- PPS plastic
- PVC-U (unplasticized, rigid)
- SAN plastic
- Unsaturated polyester composite (UP)

Woods

- Hardwood: Birch
- Hardwood: Cherry
- Hardwood: Maple
- Hardwood: Oak
- Hardwood: Walnut

Appendix B: Eco-Design Strategies and Material Choice

Reducing embodied energy, optimizing end-of life, and meeting regulations:

- **Embodied energy, carbon, and water:** If your product doesn't use much energy to operate over its lifespan, like furniture, then the most effective strategy is usually to reduce the embodied energy of its materials. The Eco Material Adviser provides data on embodied energy, carbon, and water.
    - Of the environmental factors measured by the Eco-Material Adviser, embodied energy is usually the most important, and is strongly correlated with the CO_2 footprint. If your material supplier or manufacturing uses a low-carbon fuel source or renewable energy, these impacts will not be as large.
    - Embodied water may be important if your product is manufactured in an area that has water constraints or issues. However, because water is a renewable resource and a product's embodied water doesn't necessarily have implications on pollution or human health, it is generally less important than embodied energy. For more information on virtual water, see Wikipedia.
- **Hazardous Substances:** You'll want to avoid hazardous and toxic substances to ensure you can sell your products worldwide, to avoid costly legislation, and, ultimately, to keep your product's users and manufacturers safe. The Eco Materials Adviser provides data on whether your materials are RoHS compliant and safe for food contact.
    - In the European Union, there is a law called RoHS (Restriction of Hazardous Substances Directive) that restricts the use of lead, mercury, and other chemicals in electronics, appliances, and toys. If a company's products contain these chemicals, they can't be sold and the company can face fines and legislation. For more information on RoHS and the substances it restricts, see Wikipedia.
    - A food contact grade is defined as a material that has passed testing protocols defined by the FDA, EU, or NSF. If the Eco Material Adviser indicates a material is safe for food contact, it means that there are commercially available food contact grades available within that material specification. It does NOT mean that all grades of the material are for food contact use. Check with the supplier.
- **End of Life:** At the end of a product's life, it can be landfilled, recycled, or downcycled. If the materials can be re-used, then the product will have a lower impact (this is automatically included in Eco-Material Adviser's embodied energy calculations – see troubleshooting section below). The Eco Materials Adviser indicates the end-of-life strategy that is most likely to be used for a material, based on current industrial practices.

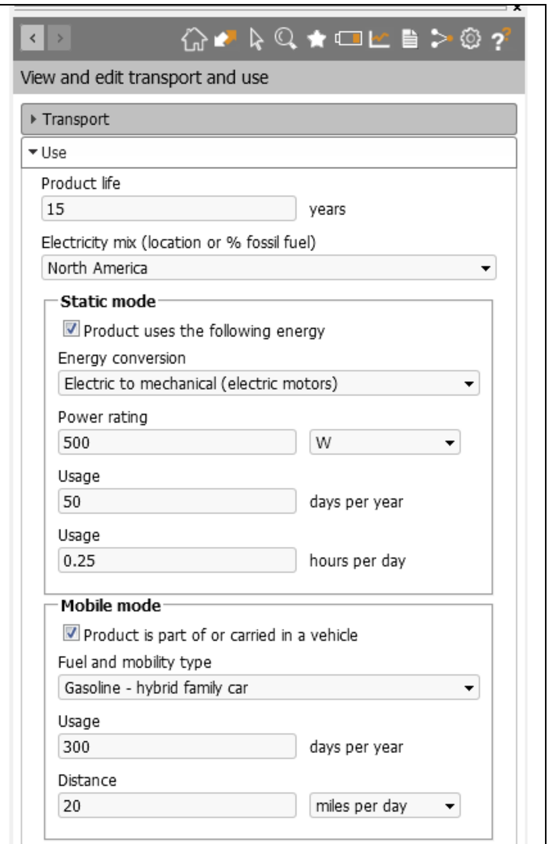
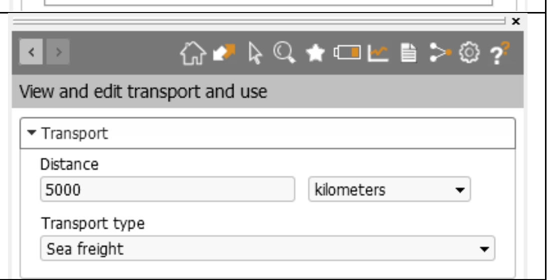
Reducing energy during use:

- **Lightweighting:** If your product moves and will use a lot of fuel or energy over its lifespan, like a car, then the most effective strategy is usually to reduce the mass of what you need to move around. The Eco-Material Adviser can help with this by allowing you to search for materials with the right strength and density characteristics.
- **Optimizing Thermal Performance:** If your product primarily uses fuel or energy to heat or cool, like a refrigerator or an oven, then the most effective strategy is usually to improve its thermal properties to optimize heat transfer. The Eco-Material Adviser can help with this by allowing you to search for materials.

The data provided by the Eco Materials Adviser is often sufficient for making informed material selections, especially early in the design process. For more detailed information on the environmental impacts of your design and its materials, you may want to do a more thorough Life Cycle Assessment (LCA). For more information on LCA, see the LCA Primer on the Autodesk Sustainability Workshop or Wikipedia.

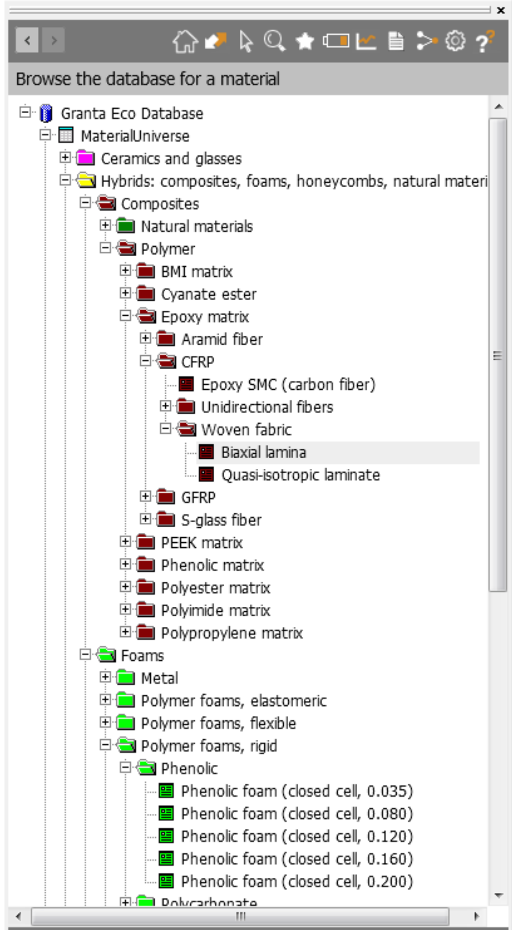
Appendix C: Full Version Features

In addition to the features of the free, base version of the Eco Materials Adviser, the full version allows analysis of full assemblies, use phase impacts, transportation, and thousands more materials. Please see [Granta's website]() for more information. A quick summary of these features is below.

Use Phase Impacts Energy from the use phase often accounts for the largest environmental impact. With the full version, you can analyze these impacts based on how your design uses energy (does it convert electrical to mechanical energy through an electric motor?) and based on whether it is part of a moving vehicle (is it something like a car bumper that's carried around on a vehicle?).	
Transportation Impacts Analyze the impacts of distribution via ocean, ground, or air logistics.	

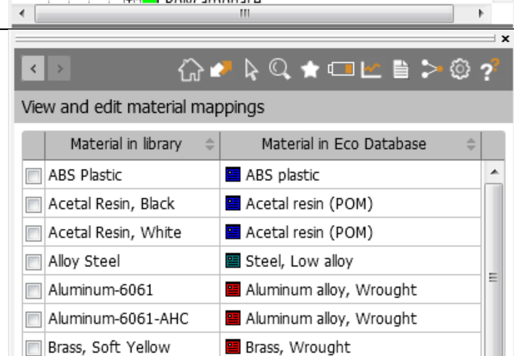
3,000 Materials

Access Granta Design's Material Universe, which includes a very comprehensive set of materials, organized within a rigorous taxonomy. This library includes composites and many more options for plastics, metals, and alloys.



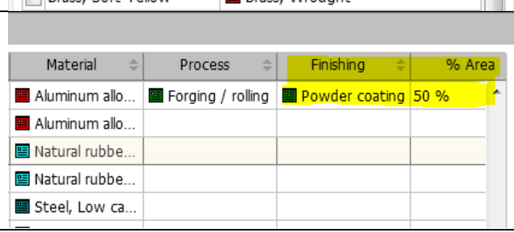
Mapping Custom Materials

You can associate materials in Granta's library with materials in your materials library in Autodesk Inventor.



Secondary Processes (finishes)

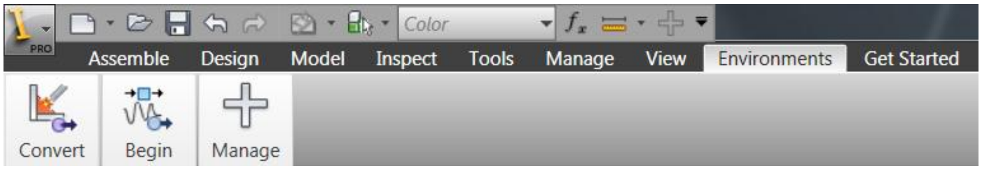
Analyze the impacts on carbon, water, and energy of using finishes like paints and powder coating. You can designate the percentage of each part that gets finished (i.e. inside not painted).



Appendix D: Troubleshooting

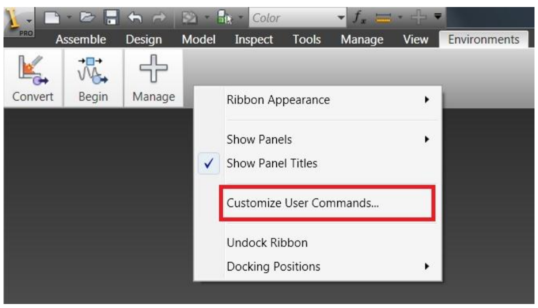
Missing Eco Materials Adviser Icon

Problem: The Eco Materials Adviser icon doesn't show up in the Environments ribbon.

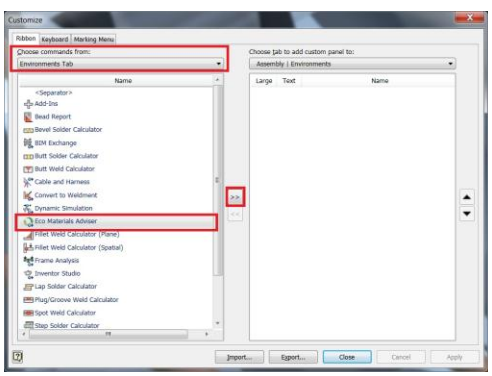


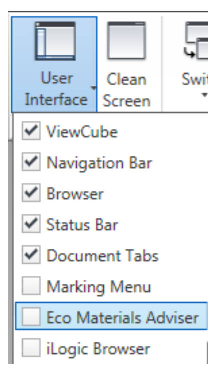
To fix this issue:

Right click anywhere on the ribbon and select "Customize User Ribbons"



From the window that opens, we will add the Eco Materials Adviser Button. In the "Choose commands from:" pull down menu, select the "Environments Tab". From here, click on the Eco Materials Adviser and press the arrows on the right.





Then, select "Apply", and the Eco Materials Adviser is now part of the Environments Ribbon.