MATERIALS

Five Steps to Eco Design

Improving the Environmental Performance of Products Through Material-led Design

Considering the potential environmental impacts of a product as part of the design process is fast becoming a primary design driver, with companies setting public, tangible, goals to reduce emissions and drive toward net-zero carbon emission targets. Active board members and investors are demanding progress on their product's sustainability, and engineers are quickly adapting to the urgent realities of eco design.

This white paper aims to provide a simple introduction to eco design through material-led design. We start with some of the business drivers to help you evaluate investing in this area. In Section 2, drawing on our experience in helping companies implement eco design activities and tools, we present some of the challenges organizations often face when starting out in this area. In Section 3, we share five simple and practical tips that can help you and your organization implement eco design, whether you are a designer, engineer, environmental specialist, or someone involved in the management of product design or development. We introduce the Ansys Granta technology that can support your eco design activities in Section 4 before summarizing the key points for incorporating environmental sustainability into product design in Section 5.

/ 1. Business Drivers for Eco Design

No matter the stage at which your company is in when considering sustainable design, it is important to be clear on two things: the business drivers for eco design and the potential value to the company of investing in the business drivers and potential value of eco design investment. The specifics and overall strength of the business case for eco design will vary from market to market and from company to company. As you read through the following list of commonly cited drivers for eco design, try to consider whether any are relevant to your company. If so, which are the most important?

A	Product marketing, brand value, and corporate social responsibility
B	Legislation on energy and hazardous substances
C	Cost & supply chain management
D	Stimulus for innovation

Table 1: Summary of business drivers for eco design.

A. Product Marketing, Brand Value, and Corporate Social Responsibility

Making claims about the environmental performance of operations or products is a double-edged sword for many companies. Such claims may help to increase sales, share prices, and brand value if they address environmental issues that are of concern to customers, analysts, or non-governmental organizations (NGOs); are based on solid scientific evidence; and can be independently verified by interested third parties. However, if environmental claims fail to meet any of these criteria, companies risk being accused of "greenwashing" — making unsubstantiated environmental claims or using environmental marketing on certain topics to gloss over less flattering environmental issues for the company. The simplest answer would appear to be to make no environmental claims at all. However, this in itself can damage a company’s brand or share value due to the rising expectations of investors and other stakeholders in relation to corporate social responsibility (CSR) reporting, increasing scrutiny from NGOs, and pressure from competitors.

If you choose to report on the environmental performance of your product, there are number of well-respected eco labels against which you can report (Figure 1). Some, such as the Carbon Trust's product carbon footprint product label (measured according to Publicly Available Specification (PAS) 2050), require you to calculate and report on the potential environmental impacts of your product, but do not set any minimum performance requirements. (However, applying the Carbon Trust label does at least commit you to reducing that footprint over the next two years.) Other standards, such as Electronic Product Assessment Label (EPEAT) for IT equipment or the European Blue Angel mark, set minimum performance targets that must be satisfied and verified before you can apply the label.

Customers expect to see companies acting in a socially responsible way. International Organization for Standardization guidelines introduced over the last two decade exist to provide standards for companies to establish, document, and maintain eco design. Companies must align themselves with these goals or risk becoming ostracized by a discerning public. This is an evolving target. Recently the London Declaration, approved in September 2021, outlines ISO's commitments to achieving emission reduction goals by 2050.

Figure 1: A range of eco labels

B. Legislation on Energy and Hazardous Substances
The introduction of environmental legislation is probably the most common driver for companies to initiate eco design activities. The Integrated Product Policy, adopted in 2003, has given rise to a number of significant pieces of product-focused environmental legislation that affect many types of products sold within the European Union (EU). Table 2 gives other examples from across the U.S., Asia, and Europe. As well as government laws and regulations, industry associations and NGOs are introducing standards, policies, and substance watch lists in an effort either to influence regulatory framework or help companies keep track of a complex, globalized picture. The challenge is not just one of geographical range; these legislations, regulations, and standards now cover the entire life cycle of the product, from the substances that go into its manufacture to the way that it is managed at the end of its useful life.

Life cycle energy consumption of the product	EU Energy-related Products (ErP) Directive
	Grenelle 2 regulations in France
Use of hazardous/restricted substances	EU Registration Evaluation & Authorisation of Chemicals (REACH) Directive
	California Green Chemistry Initiative (e.g. EOL for auto/aero)
	EU Restriction of Hazardous Substances (RoHS) Directive
	China RoHS
	Norwegian PoHS
	US Toxic Substances Control Act (TSCA)
	US Dodd-Frank Act
Use of batteries	EU Batteries Directive
End-of-life strategy for the product	EU Waste Electrical and Electronic Equipment (WEEE) Directive
	Japanese Household Appliance Recycling Law (HARL)
	EU End of Life Vehicles (ELV) Directive

Table 2: Examples of issues now affected by legislation.

C. Cost & Supply Chain Management
Legislation may be forcing you to consider eco design, but there can also be clear cost benefits. By taking an eco design perspective during the a product's design, companies often find that they are able to cut manufacturing costs by eliminating waste and reducing materials and energy use. In addition, assessing the risks associated with critical materials early in design can minimize supply chain disruptions by allowing designers to avoid using risky materials. To successfully adopt eco design, both cost savings and sustainability need to be considered together, requiring an evolution in the day-to-day behavior of engineers.

When the major environmental impacts of a product are related to a sub-system or component that is designed and manufactured by a supplier, eco design can provide a good opportunity for engagement with these suppliers. This may result in a leaner, more cost-effective supply chain. This is certainly an ambition of companies such as WalMart and Procter & Gamble, which have extensive supply-chain reporting initiatives. These companies are asking suppliers to report on environmental issues such as embodied energy, water footprint, and CO_2 emissions. These data are then used to benchmark supplier performance and identify the environmental hotspots in their supply chain, thus reducing costs.

D. Stimulus for Innovation
Companies can also discover opportunities for innovation when they consider the potential environmental impact of their products. For instance, Lightweight Medical developed the award-winning transport incubator. The use of carbon fibers makes it >50% lighter than existing models, enabling easier movement and reductions in associated transport emissions. The Dyson Airblade hand dryer uses high-efficiency electric pumps to force air through specially designed apertures that "cut" water off the hands of the user as they slowly lift their hands out of the drying chamber. By blowing water off the hands rather than trying to evaporate the water off as conventional hand dryers do, Dyson claims that the Airblade requires ~77% less time and uses up to 80% less energy to dry hands. In this way designers and producers can deliver both functional benefits and environmental benefits.

E. Pressure from Investors
Through a combination of public opinion, climate change science, and boards and company directors recognizing the importance of sustainability, corporate objectives around sustainability are becoming mainstream. These objectives are becoming more tangible and public as part of companies end-of-year reporting and aligned with director remuneration. It's becoming critical to product designers to align with these strategic objectives and ensure that both embedded and in-use CO_2 is being considered at every stage of design of the next generation of products.

/ 2. The Challenge of Implementing Eco Design

Typical Responses to Eco Design Drivers
If your company has decided that the business case for eco design is sufficiently strong, the first task is to establish how to respond. To date, many companies have focused on reporting environmental performance and assessing the compliance of products against environmental regulations or standards. Initially, many environmental marketing claims were based on limited evidence or were misleading in some cases. This resulted in backlash from environmental NGOs and consumer groups, who demand greater transparency in these environmental claims.

"To improve the environmental performance of products, we must embed practical eco design tools and approaches early in the regular design process."

Guidance is now available on how to conduct a life cycle assessment (LCA) and how to communicate the results. Standards such as the ISO 14040, ISO 14001 and ISO 14020 series have helped to significantly improve the quality and transparency of environmental claims. Conventional LCA methods and technology, with their focus on detailed analysis of environmental impacts of existing products, are probably the best-known class of tool for analyzing environmental impacts. The downside of these approaches is that they are aimed at use late-on or after the design process, and are too data- or effort-intensive to be adapted for use in an iterative manner early in design. They are thus of limited use in making practical improvements to the current or future generation of a product by design or simulation engineers trying to decide on what materials to consider for the product they're working on.

Despite market pressure, the idea of addressing environmental impact during early design is still in its infancy. Such assessment is seen as the preserve of dedicated eco specialists and consultants, as they often find it hard to engage: They often find it hard to engage engineers and designers across the company in improving product sustainably.

This white paper is based on the belief that we need to embed practical eco design tools and the right data — such as water consumption, embedded energy, or the carbon footprint for a chosen material — into the regular design processes and engineering tools (CAE, CAD, PLM) for the engineers actually designing the product and components.

The Challenges
Before considering how to achieve this goal, why is eco design not already integral to the design process?

- **Limited Time**: Environmental impacts are just one of many constraints a designer must consider during product development. Designer engineers are constantly battling to balance often-conflicting project requirements such as functional performance, cost, aesthetics, regulatory compliance, and lead time. Eco design adds yet another issue to consideration to this list, but having it as part of an early design trade-off is critical to make the right product decision as early as possible.

- **Poor integration with design activity:** When eco design activities are treated as a separate stream distinct from mainstream product development activities, they struggle to gain acceptance and quickly become marginalized. This is compounded by the fact that companies often employ environmental experts, either as consultants or as part of an Environment, Health & Safety (or similar) team, to consider environmental performance and undertake environmental assessments. If the environmental expert is not in regular contact with the design team, the results of their analysis can often be ignored — either because the analysis is not presented in a way that is accessible and useful for designers, or because there is little follow-up to ensure that the analysis leads to design improvements.

- **Increasingly complex and rapidly developing legislation**: As we saw in Section 1B, product-focused legislation, regulations, and standards are becoming increasingly complex and demanding. Simply keeping track of their potential implications is a major IT challenge that most companies have not begun to address.

  Take two examples:

  - The Energy-related Products Directive, which provides a framework for setting eco design targets for products such as high-definition televisions, is a requirement for CE marking in the EU. But the range of products affected is expanding and the implementing measures set targets that become more stringent over time. How do product development projects keep up to date?

  - The REACH Directive's list of Substances of Very High Concern (SVHC) currently contains 219 substances (as of July 2021). But this list will be updated roughly every six months, with around 25 substances being added each year. These substances may be present, or used in the processing of, thousands of materials and coatings. As the list develops, how do companies gather substance declarations from suppliers and continually assess the risk across their product portfolio?

- **Designers' Requirements Not Considered:** To improve the environmental performance of a product, you must first understand when and where environmental impacts occur across the product life cycle. The primary tool for building this understanding is life cycle assessment (LCA). Unfortunately, many of the commercially available software packages that enable LCA studies have been developed with LCA practitioners in mind, requiring expert knowledge of LCA methodology to conduct the analysis and interpret the results. Most designers and engineers do not possess this knowledge, which creates a major barrier to implementing eco design. Furthermore, LCA software is unsuitable for use during the early stages of the design process because it often requires detailed information about how the product is manufactured and used, as well as the input of data that is unfamiliar or unavailable to designers.

- **Lack of Commitment / Fear of Cost:** Design teams are sometimes reluctant to begin eco design activities because of concerns about the true level of commitment behind their company's rhetoric about wanting to improve a product's environmental performance. This may be because companies have perceived eco design as a nice-to-have capability. as they begin to investigate implementing eco design in today's manufacturing organization, they are overwhelmed and quick to dismiss it as being an unnecessary and costly activity.

/ 3. Five Steps to Get You Started

In the remainder of this white paper, we provide five simple tips to help you overcome these challenges and enable you to introduce eco design activities within your existing design process in a cost-effective and manageable manner.

STEP 1: CONSIDER ENVIRONMENTAL IMPACT EARLY IN THE DESIGN PROCESS

It is widely claimed that 80% of a product's overall environmental impact has been "built in" by the end of the conceptual design phase (Figure 2). At this point, the designer has typically selected materials and manufacturing processes, and defined the product life cycle. These parameters constrain not just the final economic cost, but also fix many of the environmental costs.

By evaluating environmental performance during this early stage, the relative environmental costs of different options can be considered, in much the same way as economic costs or material suitability would be evaluated. This enables changes to the design before significant project costs have been incurred, avoiding costly and time-consuming redesign.

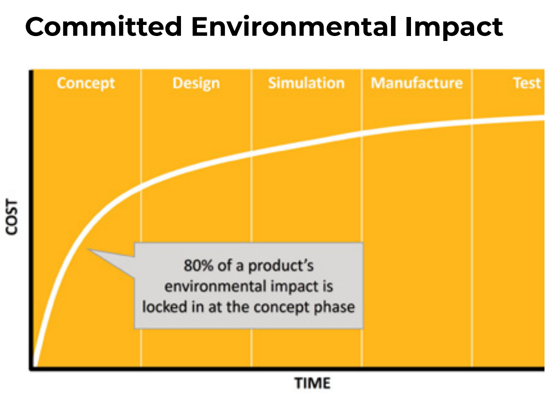

Figure 2: Illustration of design process against percentage of environmental impact fixed.

STEP 2: IMPRECISE DATA CAN GUIDE GOOD DECISIONS

Engineers and designers who are used to the precision with which physical properties are measured can be disconcerted by the imprecision of eco data where values are, at best, known to within 10%. However, it is important to realize that this does not prevent good decision making, especially when the environmental impact of a particular life phase dominates.

For example, when selecting materials, the difference in values of embodied energy or CO_2 footprint can often be a factor of 1,000 or more, so the imprecision still allows firm distinctions to be drawn (Figure 3). When the material phase differences are small, other factors such as the recycled content of the material, its durability (and thus lifetime), and the ability to recover and recycle scrap at end of life are more significant in making the selection.

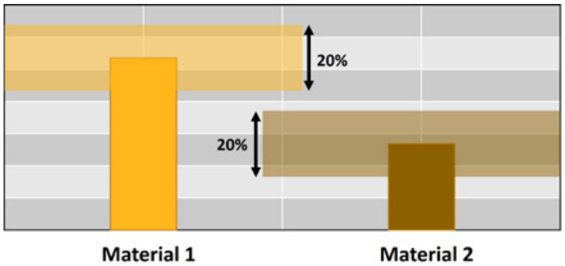

Figure 3: Firm conclusions can be drawn about the environmental impact of a material, even with imprecise data.

STEP 3: CONSIDER THE ENTIRE PRODUCT SYSTEM

Environmental performance is often significantly affected by how the user interacts with a product, how it is maintained, the operating environment, and whether it is the correct product for the user's needs. A useful tool for this is the Environmental Impact Assessment, which helps engineers consider the environmental impact of all phases of a product's life during design: material, manufacture, transport, use, and disposal (Figure 4). This encourages designers to invest the greatest effort in improving the environmental sustainability of the phases that carry the highest demand for energy or generate the most CO_2. Doing this in the early stages of design will yield the maximum return on investment.

A good example is the impact on these five variables (material, manufacture, transport, in use, and disposal) in the shift towards electrification. CO_2 impact over the lifetime for a typical internal combustion engine (ICE) vehicle is heavily skewed to the in-use phase, whereas for an electric vehicle, this impact has shifted to the materials being used, thus becoming a key element for designers.

STEP 4: MATERIALS & PROCESS DECISIONS ARE CRITICAL

Material and process decisions play a very important role in determining the environmental impacts of a product across the life cycle:

- Extraction and processing of raw materials carries significant environmental impact.
- Materials choice determines feasible manufacturing processes and associated energy and material efficiency.
- Material mass can greatly influence energy consumption and CO_2 emissions in transport and use phases.
- The substances used in materials and their recyclability/reusability characteristics determine toxicity, restricted substance impacts, and the impact of a product at the end of its life.

Some key strategies for minimizing environmental impact of each life stage are shown in Figure 4. Many relate directly to materials characteristics. One critical point is that you cannot base "eco materials selection" simply on the "eco properties" of the constituent materials, such as embodied CO_2, recycled content, or toxicity. You must assess these properties in combination with mechanical, physical, thermal, and electrical properties. For example, when reducing CO_2 emissions, it may be better to make a vehicle body out of a lightweight material such as a carbon fiber composite, even if this raises the CO_2 emissions associated with the material production and manufacturing phases. The lower mass is likely to lead to a large reduction of in-use phase CO_2 emissions, which yields overall improvement.

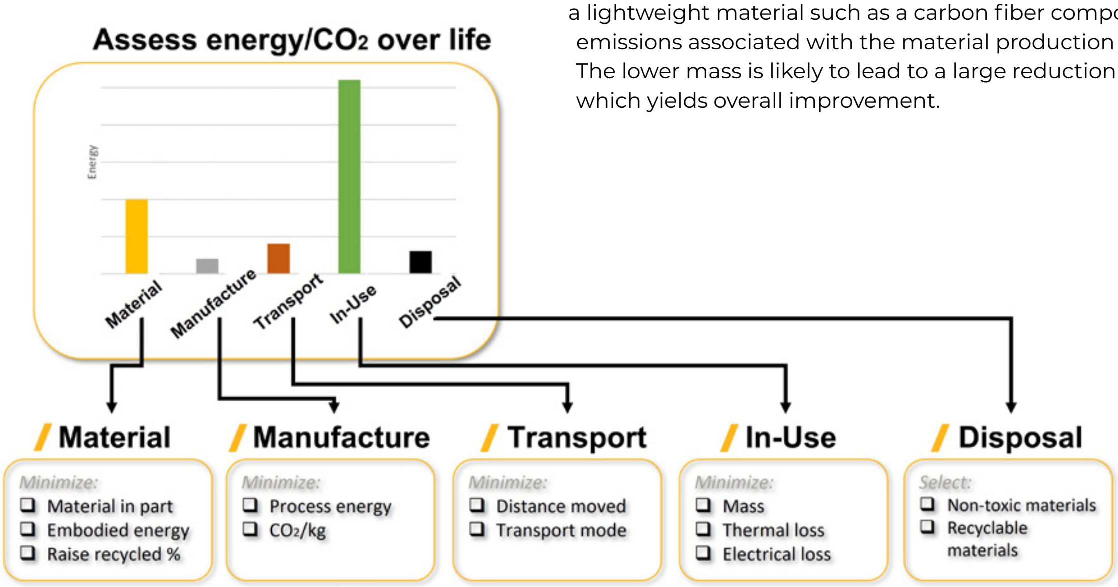

Figure 4: Environmental impact can be assessed for each life stage of a product. Materials and process selection play an important role in determining environmental impacts and can be used in many eco design strategies (Step 4).

STEP 5: ESTABLISH TARGETS AND THE INFORMATION SYSTEMS TO SUPPORT THEM

Companies that have successfully implemented eco design often have long-term, corporate-level targets for improving environmental performance. For instance, engine manufacturer Cummins unveiled a new environmental strategy timed to be implemented by 2030, which included:

- Reducing absolute lifetime greenhouse gas emissions from newly sold products by 25%
- Reusing or responsibly recycling 100% of packaging plastics

Setting this type of target has two effects. First, it demonstrates the company's long-term commitment to environmental performance, and second, it establishes a framework in which targets can be set at the project level. Some companies have found it effective to "cascade" these targets to the project level by including environmental impact reduction targets within product requirements specifications. This is because designers use product requirements to focus their design effort and assign design time.

Defining targets helps to develop the right behavior in an organization. However delivering on those targets requires the right information. Consider the challenges of legislation raised in section 2. Meeting these requires an organization to track the effect of regulations, laws, and standards on its products. In regards to tip four, this often means ensuring access to up-to-date information on the restricted substance or other environmental impacts of specific materials and process choices. Executives should not only set targets, but ask, "What systems do we have in place to enable informed materials and process decisions?"

/ 4. How Ansys Granta Technology Can Support Your Eco Design Activities

Ansys Granta's core expertise in materials and process selection and materials information management, together with our understanding of the challenges of eco design, has allowed us to develop a range of practical software tools. Granta includes supporting materials and environmental data, which enables access to a full range of material attributes. They are designed to be used during the early stages of design and simulation, where changing the material and process choices costs least but matters most (Figure 5).

A	Early Design: Eco Audit
B	Assess Product Risk
C	Material Selection & Substitution
D	Materials and Environmental Data
E	Open Ecosystem Material Intelligence

Table 3: How Ansys Granta's software can support your eco design.

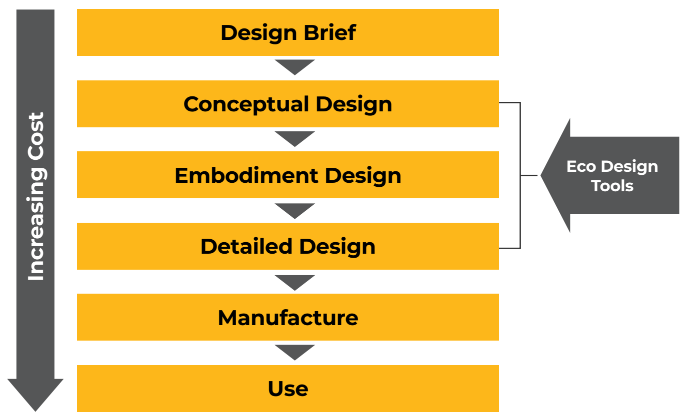

Figure 5: Ansys Granta's eco design tools meet the need for assessing environmental impact during design.

A. Early Design: Eco Audit

Eco Audit can be accessed within **Ansys Granta Selector**. Users can input a simple bill of material (BOM) for a product and add information on its transport, use, and predicted environmental impacts for each phase of the product's life cycle. (see Figure 6). Engineers can clearly identify the effects of material and process decisions and predict the embodied energy and CO_2 footprint of a product (see Step 4 in Section 3) then go on to use in-depth material selectionfeatures to identify viable engineering solutions to mitigatethese factors.

By providing a quantitative estimate of these potential environmental risks, the Eco Audit tool allow development teams to rapidly iterate different designs to look at the environmental effects of changing materials, manufacturing processes, transportation types, usage, and other factors.

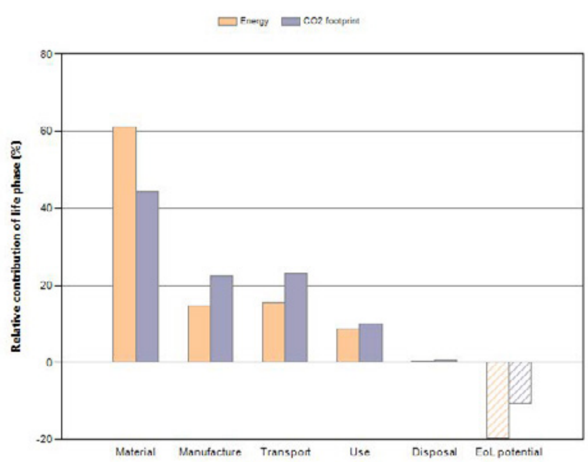

Figure 6: An example Eco Audit from Granta Selector.

B. Assess Product Risk

Granta provides tools that enable a fast and integrated view of various risk factors relating to environmental performance and regulation. Product designers can use the **Granta MI BOM Analyzer** tool, an easy-to-use web app that lets you build or import a BoM, add materials and process data, and quickly run reports on restricted substances from a variety of jurisdictions (see Figure 7). This allows teams to evaluate the impact of global legislations on their product and make "what if" decisions on the substances they include or exclude from a product. This will ultimately have a significant impact on the sustainability of a product in market, as a product that is "future-proofed" for incoming regulation and legislation will not have to be recalled or modified weight, or to cut embodied energy (see Step 2 in Section 3).

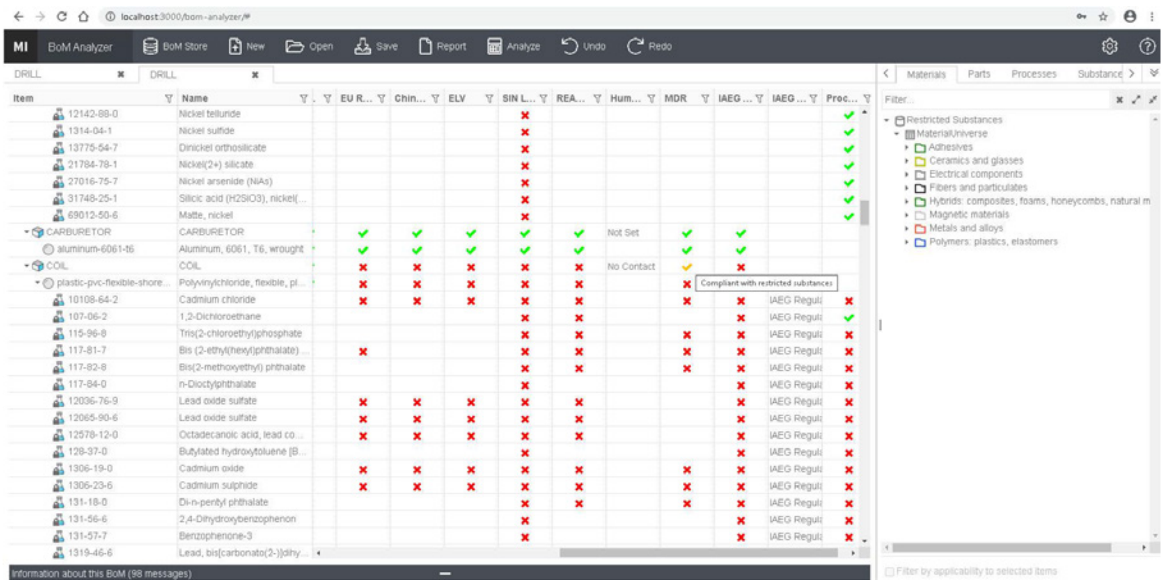

Figure 7: MI BOM Analyzer can produce a product risk report directly from a bill of materials.

C. Material Selection and Substitution

Granta has long provided powerful tools for in-depth analysis of material selection and substitution decisions through both Ansys Granta MI and the PC-based Ansys Granta Selector software. Engineers and designers can search and browse materials data — including technical, economic, and environmental properties — and combine and use that data to enable rational materials selection through tools such as materials property charts (Figure 8).

These tools help users to ascertain which materials meet the engineering constraints of their application, rank materials against design objectives, and investigate trade-offs. In practical terms, users of Granta tools have used this to:

1. Execute lightweighting opportunities by replacing aluminum components with polymers for 45% savings in weight.
2. Increase recyclability of a single-use product to decrease a product's carbon footprint twofold over its lifetime.
3. Reduce the carbon footprint by 10-15% for specific filling applications in the high tech industry
4. Better material reuse and reduced wastage by expanding tool lifetime by a factor of six in volume manufacturing

If these tools suggest new material and process options, the Eco Audit methodology makes it easy to test the environmental impact of those changes.

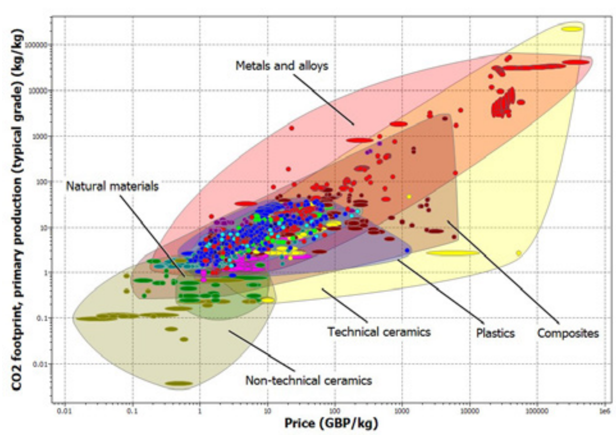

Figure 8: Ashby diagram showing CO_2 footprint versus price per kilogram. This method enables users to make rational materials decisions based on technical, economic, and environmental factors.

C. Materials and Environmental Data

The tools described above all require the right data. Granta not only embeds this data within its Eco Audit, materials selection, and restricted substance software, it also provides it as a unique series of reference data modules (Table 4), enabling users to search and browse to find specific information. All data is compiled and reviewed by subject experts from some of the best sources available; details of data sources are provided within the data modules, providing full traceability.

Data Module	Content Summary	Attributes and Properties
MaterialUnivers Eco Data	Generic property data on 4,100+ engineering materials and 240 processes, allowing comparison and selection for metals, ceramics, polymers, composites, and natural materials	For each material: up to 60 engineering properties, 25 eco properties (e.g., energies, emissions, end-of-life), plus cost data
Restricted Substances	Covers 11,000 substances and more than 125 national and international regulations, legislation lists, and industry standards that impact those substances	Substance records provide property information and links to relevant regulations. Legislation record describes the regulation and links to records for affected substances
Coatings	Describes 140+ coatings and 450+ surface treatments. Helps decisions, particularly relating to restricted substances	More than 60 attributes per coating: e.g., mechanical properties, restricted substances, cost, substitution
Critical Materials	Identify and understand materials supply risk based on factors such as geopolitical risk, physical scarcity, coproduction risk, conflict mineral risk, and price volatility	Supply risk data for 67 key elements, including rare earths. Elements can be linked to 3,500+ materials, enabling you to identify those at risk
ecoinvent Key Materials Indicators	Key materials indicators and background information from ecoinvent, enabling the environmental impacts of materials, chemicals, and processes to be assessed and compared in Granta software	Four environmental impact indicators alongside background information for each material or process, as provided by the ecoinvent database from the Swiss Centre for Life Cycle Inventories

Table 4: Unique material data from Ansys' extensive library of reference data.

E. Open Ecosystem Material Intelligence

One key concept throughout this white paper has been embedding environmental considerations into the routine design process, as early as possible. One obvious way to do this is to provide these practical eco design tools within routine engineering and business software — for example, within computer-aided design (CAD) and computer-aided engineering (CAE), and product life cycle management (PLM) systems.

The MI Materials Gateway technology enables this functionality. It allows Granta to integrate tools directly into Ansys and third-party software, acting as a single point of truth for all material attributes. In principle, the tools and data described are provided within the user's native design environment — no tool-hopping required.

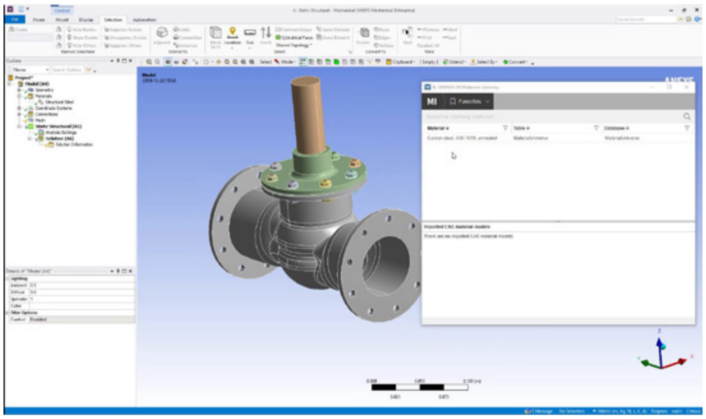

Figure 9: The MI Materials Gateway tool can be used across a wide range of CAD, CAE, and PLM solutions. Seen here with Ansys Workbench.

Many levels of integration are available for a number of leading CAD, CAE, and PLM systems: BetaCAE ANSA®, Altair Hypermesh®, Simulia Abaqus, Siemens NX® and Teamcenter®, PTC Creo®, and Windchill® amongst others.

The MI Materials Gateway enables instant access to approved materials data for simulation directly within leading CAE software. Users can also search and browse the materials, view datasheets, and import applicable CAE materials models directly to the CAE environment, complete with full traceability information. These tasks are performed interactively with no risk of error due to data transfer. Key materials data can also be exported into several of these Ansys and third-party environments from Granta Selector.

	Granta MI Enterprise	Granta MI Pro
Ansys Workbench	✓	✓
Ansys Minerva	✓	
Ansys Discovery	✓	✓
Ansys Electronics Desktop	✓	✓
PTC CREO	✓	✓
PTC Windchill	✓	
Siemens NX	✓	✓
Siemens Teamcenter	✓	
Altair Hypermesh	✓	✓
Simulia Abaqus	✓	✓
BetaCAE ANSA	✓	
Python tools	✓	

Figure 10: A list of some of the possible integrations between Granta MI and leading CAE, CAD, and PLM solutions.

/ 5. Summary

This white paper has provided an introduction to the topic of eco design. We began by discussing some of the commonly cited drivers for eco design. It is crucial to develop a sound business case by identifying which of these drivers are relevant for your company. Having acknowledged the challenges commonly encountered, offered five simple steps to help you achieve your eco design goals (Figure 11).

For Everyone	For Designers, Engineers, and Materials Engineers			For Managers
Tip 1	**Tip 2**	**Tip 3**	**Tip 4**	**Tip 5**
Consider environmental performance early in the design process	Imprecise data can guide good decisions	Consider the entire product system	Materials and process decisions are critical to environmental impact and eco design	Establish targets and the information to support them

Figure 11: Five steps to eco design.

/ Request Your Demo

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