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WHITE PAPER

Sustainability for Manufacturers: Driving Profitability and Growth

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Contents

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Introduction

Sustainability is an increasingly common theme in the business and trade press, at conferences, and in everyday conversation. This white paper encourages manufacturers to integrate sustainability into their corporate strategy to drive both profits and growth. It reviews the top environmental issues affecting the manufacturing sector and explains how taking action on sustainability can help mitigate perennial business challenges. It also outlines a sustainable design methodology that can assist in lowering the environmental impact of any product, quickly and cost-effectively, with the help of advanced design software tools.

Sustainability: What It Is and Why It Matters

Sustainability is usually defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."[1] The sustainability of a manufacturer is measured by the effect of its operations and its products throughout their lifecycle. Issues related to sourcing (where applicable), downstream impact, and strategies are addressed below in the context of the most pressing environmental matters of the day.

[1] World Commission on Environment and Development (the Brundtland Commission), 1987.

Materials

Sourcing

Manufacturers use raw materials as inputs and transform them into finished goods. Materials like wood, copper, and steel were once cheap and plentiful, but are growing ever more expensive and harder to find. Cost and availability are likely to worsen as rapid growth in newly industrializing countries consumes natural resources faster than they can be replenished or substitutes found.

Impact

The harvest and extraction of natural materials can cause substantial environmental harm, especially as supplies dwindle and resource recovery becomes more invasive. Industrial materials often emit pollutants as by products of their production process. A lifecycle assessment of a manufactured good will include the environmental impact of the product's material inputs as well as the production process. The lifetime impact of a product may vary significantly based on the materials selection and on the amount of materials consumed.

Strategies

All manufacturers can minimize environmentally related business risks by using materials efficiently—the minimum necessary to do the job—and when feasible, choosing materials that are:

- **Plentiful—**such as rapidly renewable natural materials such as bamboo or readily available industrial materials such as recycled aluminum, and
- **Healthy and safe—**not subject to regulations, restrictions, grassroots campaigns or questions about their environmental impact on humans, wildlife and habitat.

Water

Sourcing

Manufacturers often use water as an input in the production process, and some industries are particularly water-intensive.[2] Only a tiny fraction of the planet's water is fit for human consumption, and the amount is shrinking fast as aquifers are overdrawn, chemicals leach into groundwater, and climate change shrinks lakes and reservoirs. Seasonal and crisis-related shortages are common in some regions and likely to increase in coming years. At-risk communities are increasing their reliance on recycled water to meet the non-potable needs of residents and businesses. As humans, wildlife, agricultural, and commercial interests increasingly compete for access to clean water, the price of water is steadily climbing. Many observers predict that future wars will be fought over water.

Impact

Manufacturing processes that use water frequently emit wastewater containing chemicals, suspended solids, and other impurities. Depending on its composition, the wastewater may be subject to local health regulations and require expensive treatment and remediation. Even non-hazardous wastewater (sewage) rates can be expensive.

Strategies

Manufacturers can reduce costs and risks related to water and wastewater by:

- Minimizing the overall use of water in their manufacturing processes;
- Using recycled water rather than potable sources;
- Minimizing contaminants in wastewater, and
- Investigating the feasibility of capturing, recycling, and reusing water onsite.

[2] Examples include pulp and paper, photographic film, textiles, leather, metal smelting, chemicals, semiconductor chip fabrication.

Energy

Sourcing

Virtually all manufacturing processes use energy. Regardless of type and source, energy prices have escalated over the past 35 years. Unless manufacturers have invested in energy efficiency, energy costs now represent a larger share of operating expenses than ever before, with no end in sight. The electric grid infrastructure is aging, inadequate and vulnerable to outages in many parts of the world. On-site power generation and alternative sources may be more reliable in some instances than power purchased from a central utility.

Impact

Worldwide, most energy is produced by the combustion of carbon-based fossil fuels such as coal, gas and oil.[3] The resulting greenhouse gas emissions are a major cause of global warming and increasingly subject to regulation. Large emitters—including businesses that consume large amounts of electricity and natural gas [4] —are or will soon be required to monitor and report, then limit their output. The more carbon-based energy a manufacturer uses in its operations, the more affected it will be by reporting requirements, emission limits and carbon taxes. Its higher operating expenses will be reflected in its higher cost of goods.

Manufacturers also need to consider the energy cost and related emissions of packaging and shipping their raw materials, component parts, and finished goods. If products are made or assembled in developing countries for sale in industrialized regions, the overall energy footprint may skew heavily toward transportation.

Purchasers also care about the energy consumption, financial and environmental impacts of a product. If machinery or a consumer product is designed to run on electricity or a carbon-based fuel like oil, coal or natural gas, its total cost of ownership will increase proportionally with its energy consumption. The energy efficiency of a product is a newly important feature and competitive differentiator.

Strategies

As a hedge against future cost increases and a way to improve competitiveness, all manufacturers are encouraged to:

- Minimize the energy used in operations, both in business operations and manufacturing processes;
- Minimize the energy consumed by products during their useful life;
- Limit product packaging and shipping distances when possible, and
- Consider using clean, renewable energy to meet some or all operational needs.

Waste

Impact

Worldwide, the problem of waste is growing acute. Landfills are at capacity and difficult to site; decomposing trash emits greenhouse gases more potent than carbon dioxide, and escaping chemicals can contaminate the soil and water supply. Incinerators are under pressure to close because they emit benzene and chlorine, carcinogens that endanger human health and the environment. In response to the growing acknowledgement that there is no place on earth to throw things "away," more than 50 government entities worldwide have adopted a goal of zero waste.[5] High waste disposal fees reinforce the policy, and are common anywhere waste disposal options are scarce.

Pollution is another form of waste, one with a clearly negative impact on the environment. Particulates, gas emissions and the solids found in wastewater, sludge and ash can all cause significant harm to humans and habitat. Pollution mitigation measures are required under local, state and/or federal regulations, and compliance measures can be expensive. Failure to comply with regulations can lead to steep penalties, possible civil and criminal litigation and consumer boycotts.

Manufacturers must consider the waste produced by their products as well as their operations. Products that generate unwanted by products will be more costly and troublesome to their purchasers than ones that operate more efficiently. Products covered by extended producer responsibility policies, either mandatory[6] or voluntary[7], will impose higher costs and hassles on manufacturers if they are not designed for efficient disassembly and resource recovery.

Strategies

Waste is a symptom of a non-optimized manufacturing process. Any unwanted byproduct increases expenses-and the cost of goods-but does not increase the product's value or selling prices. However, what constitutes waste for one business may be a valuable input for another. Transferring unwanted byproducts to another manufacturer is a financially sound business practice, regardless of whether a fee is collected. Eliminating waste by improving the efficiency of the process is an even more cost effective practice.

Every manufacturer can increase profitability by reducing its waste stream. This can be achieved by:

- Estimating and buying materials accurately, and using them efficiently;
- Improving process efficiency,
- Controlling pollutants, and
- Finding a productive (and ideally, profitable) use for industrial outputs.

[3] The next largest sources, nuclear and hydropower, offer different challenges. Disposing of nuclear waste is problematic environmentally, politically and logistically. Hydro is clean and renewable but vulnerable to drought. Water allocation often pits power against habitat and species needs.

[4] The EU Emissions Trading Scheme applies to combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, brick, ceramics, pulp and paper. http://ec.europa.eu/environment/climat/pdf/mo6_452_en.pdf. California's mandatory emissions reporting will likely apply to the cement, electric power, refineries, hydrogen plants, and cogeneration sectors, but may also affect large emitters in the food processing, mineral processing and malt beverage industries. http://www.arb.ca.gov/regact/2007/ghg2007/isor.pdf, p. 51 (p. 67 of pdf).

[5] Its proponents define zero waste as "... designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water or air that may be a threat to planetary, human, animal or plant health." Zero Waste International Alliance, http://www.zwia.org.

[6] E.g., the European Union requires producers of batteries, electrical and electronic equipment, oil, packaging and vehicles to take responsibility at the end of a product's life. http://ec.europa.eu/environment/sme/legislation/waste_en.htm#1.

[7] Computer manufacturers Dell and HP, among others, have embraced voluntary takeback schemes in some markets.

Regulatory and Voluntary Standards

Impact

The use and disposition of specific material inputs is increasingly subject to regulations intended to minimize environmental harm. The European Union uses the Precautionary Principle[8] as a key element of its environmental policy. Its recent Restriction on Hazardous Substances (ROHS)[9] and Waste Electrical and Electronic Equipment (WEEE)[10] directives have already reshaped the electronics and computer industries; the newly enacted Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)[11] directive will have an even more profound impact on a wide range of companies. Europe's actions affect all manufacturers and are likely to be adopted in other regions.

"Soft" requirements, while not legally enforceable, are also gaining momentum. The media and the market are beginning to demand that companies publish information about their product contents, corporate emission levels and climate action plans. Grass roots campaigns targeting the use of specific materials (such as polyvinyl chloride, or PVC) may affect consumer preferences, spur lawsuits and foreshadow regulatory action.

Voluntary certifications are yet another emerging market factor. Materials or products that comply with a published standard (such as Forest Stewardship Council certification for sustainably harvested lumber and GreenGuard certification for low-emitting products) are eligible to use the seal in their marketing materials. Since certification programs exist at many levels, a certified material (FSC lumber) can be used in a certified product (GreenGuard flooring), which can in turn contribute toward another kind of certification, a LEED rating for buildings.[12] The effort and expense of the certification process is offset by a growing market preference for environmentally superior options. The number and type of voluntary certification programs expands every year.

Strategies

To facilitate compliance with environmental regulations, manufacturers are advised to:

- Monitor the regulations that govern their products;
- Understand the environmental impact of their products and source materials;
- Track emerging policies and public opinion affecting same, and
- Take preventive action by reducing the environmental impact of their products, diversifying by adding a "green" product in the same space, and/or preparing a market exit plan.

To enhance the market position of a product, manufacturers may wish to:

- Consider which (if any) certification programs will advance their competitive position;
- Analyze the costs and benefits, both short- and long-term, of compliance and certification;
- If merited, pursue certification, and
- Market to customers with an environmentally preferable procurement policy and those pursuing certification of their own offerings.

[8] The Precautionary Principle is based on the premise that when the health of humans and the environment is at stake, it may not be necessary to wait for scientific certainty to take protective action. http://www.sehn.org/ppfaqs.html.

[9] ROHS restricts the use of six hazardous materials in the manufacture of electronic and electrical equipment. Manufacturers scrambled to find benign alternatives to lead, cadmium, and the other banned materials, or risked incurring heavy fees and closed markets.

[10] WEEE requires makers of electrical goods to meet specific collection, recycling and recovery targets for their products at end of life. Affected manufacturers needed to develop a reliable mechanism for reclaiming product from the consumer.

[11] REACH requires the testing and registration of most chemicals manufactured in or imported into the EU. Producers and importers may be required to test and report the effects of particularly risky chemicals, and the most hazardous (carcinogens, reproductive toxins, or those that accumulate in humans or animals) can only be used if expressly authorized by the European Chemicals Agency.

[12] LEED is the acronym for Leadership in Energy and Environmental Design, a voluntary and widely adopted rating system for buildings.

The Business Benefits of Sustainability

The increasing importance of environmental issues to manufacturers poses risks and offers opportunities. The following section briefly connects the opportunities to the business challenges commonly faced by producers.

Profitability

- Using less energy in the production process lowers overhead and product costs. Companies that lower their cost of goods and operations have more money to invest in R&D, upgrading plant or equipment or capital improvements, all of which can contribute to greater competitiveness and long-term success.
- Using fewer materials also cuts costs. Switching to more sustainable materials may or may not reduce costs at the front end, but will likely reduce waste, emissions and pollution, and perhaps avoid shortages or price increases for the less-sustainable material.
- Companies that use natural resources wisely and take positive steps to lower their environmental impact are more successful in attracting and retaining loyal customers and staff.
- Manufacturers that take responsibility for their products after point of sale can sometimes create an annuity-based service business.[13]

Competition

- Sustainability is still a differentiator, but not for long–it is quickly becoming an expected part of doing business in the global economy.
- Customers claim in surveys that they are willing to pay more for a safe, healthy, green product. Recent concerns about the presence of dangerous chemicals and materials in imported goods give domestic manufacturers a chance to regain market share for some types of consumer goods.
- Products that use minimal energy and water during their useful life will cost less to own and operate than less resource-efficient alternatives.

Compliance and Managing Risk

- Regulatory pressures will continue to increase and expand to cover materials and products whose cumulative environmental impact is deemed unacceptable (such as non-biodegradable plastic).
- Pro-actively reducing the carbon and chemical footprint of a business now can avert or minimize negative regulatory impacts later.
- A sustainable approach reduces risks at every stage of business, leaving businesses less exposed to the possibility of materials shortages, energy price increases, higher fees for waste disposal and pollution abatement, liability and unwelcome shareholder actions.

Market Opportunities / Growth

- Major corporations and public agencies are increasingly demanding emissions reporting and mitigation plans from their supply chain partners.[14] Suppliers who can show an understanding of the issues and progress toward goals will win business away from those that do not.
- Earning a valued third party certification designation puts products on the short list for businesses and government agencies that have implemented an environmentally preferable purchasing policy.
- Sustainability challenges are spurring the need for new solutions. Manufacturers that can add or extend an existing product line to meet the challenges have huge market opportunity.

[13] Caterpillar built a $1 billion business out of refurbishing its construction equipment. Its pricing model incents customers to return old equipment and get a refurbished replacement at half-price, thus locking in the customer for life. Interface International sells floor covering services for a monthly fee rather than selling a carpet once every several years. Interface replaces worn areas with new carpet tiles, and then recycles the worn tile, conserving resources and increasing profits.

[14] For example, Walmart recently announced that it will measure the energy use and greenhouse gas emissions of its entire supply chain in seven product categories; beer, DVDs, milk, soap, soda, toothpaste and vacuum cleaners.

Implementation Options

Manufacturers can lower their expenses by improving the resource efficiency of their operations in the front office, back office and factory. Opportunities for growth will come from improvements in product design.

Business Operations

Improving energy efficiency in offices and factories is usually a relatively easy and cost-effective way to enhance environmental performance. Energy audits (often provided free of charge by the local power utility) consistently find savings opportunities in lighting and HVAC systems. Many times, capital improvements such as adding insulation, upgrading windows and installing variable frequency drive pumps offer quick paybacks as well.

Beyond energy efficiency, the following kinds of projects are relatively simple to implement and offer an attractive return on investment:

- Using low-flow aerators in faucets and showers;
- Installing high-efficiency toilets, sinks and appliances;
- Using energy-efficient office equipment and computer settings;
- Increasing the fuel efficiency of the fleet, and
- Eliminating unnecessary business travel.

Production Process

The manufacturing process is resource-intensive by nature. Common sense dictates that using less energy and water during production and reducing materials waste will help a business lower its costs and operational footprint. In reality, however, some producers may be reluctant to modify familiar processes based on the chance that they can create the same quality product with fewer resources. The costs of downtime, retooling, worker retraining, safety and performance testing are well known to manufacturers; the benefits of a greener operation are theoretical until proven.

Two factors reduce the risk of updating a production process to improve its sustainability: one is using a proven methodology and the other, a proven technology. Lean Manufacturing and SixSigma are well-known process improvement methodologies that target and eliminate waste to drive profitability; they usually improve the environmental performance of a process at the same time. Using a sustainable design methodology that borrows key elements from Lean and SixSigma can help a producer target areas for improvement efficiently and effectively, with minimal risk.

The other way to reduce risk is to take advantage of the latest software technology. Businesses that use a design platform with digital prototyping capabilities, such as Autodesk® Inventor™ software, can develop a single 3D model that evolves from concept through manufacturing. The model allows the designer to evaluate opportunities to reduce environmental impact throughout the manufacturing process—for example, by reducing weld energy through optimization of material thicknesses in an assembly.

Product Design

The greatest environmental impact of some products comes not during their manufacture, but during their useful life. Industrial equipment, consumer electronics, cell phones—anything with an on/off switch—may consume many times more energy in a year than was consumed during its production or embedded in its raw materials. In other cases, the choice of materials may be the most critical environmental factor associated with a product. Both issues are of growing importance to customers, supply chain partners and regulators. Products with low eco-footprints offer a lower total cost of ownership, less chance of liability and fewer regulatory hurdles for producers and buyers alike. In short, such products are more competitive than their traditional counterparts are and may fuel a manufacturer's growth.

To minimize the lifecycle impact of a product, producers can use a sustainable design methodology modeled on proven improvement methodologies. Like Lean and SixSigma, sustainable design "starts with the end in mind," a clearly defined desired outcome or end state. Because the interplay of inputs and process steps dictates the outcome of a process—or in this case, a product—sustainable design practitioners work backward and analyze the impact of materials choices and production processes on the product's overall sustainability and the desired outcome. Understanding the interplay allows a designer to modify elements of the process as needed to achieve the desired result. In SixSigma terms, the process output is a function of process inputs (Y= f(X)), so achieving a specific outcome involves manipulating the input variables until the desired result is achieved.

Manufacturers should choose sustainable outcomes that advance their top business priorities, such as lowering operating expenses or taking market share from a competitor. Business conditions such as cash flow, market trends, materials availability, and regulatory constraints may influence the selection. The chosen outcome will guide the product strategy and determine trade-offs, so the entire team must have a shared vision of the outcome throughout development and production. The more specific the desired sustainable outcome—such as an air conditioner that uses environmentally benign refrigerant or a zero-emission motorcycle—the easier it will be for the team to focus on the inputs and process variables that might achieve the intended result.

Examples of the benefits, beneficiaries and strategies of three possible high-level outcomes (resource efficiency, carbon neutrality and health and safety) are summarized below.

Outcome	Benefits	Most applicable to	Strategy
Resource efficiency	Saves money for manufacturer, lowers COGS; energy-efficient products lower the customer's cost of ownership	Low-margin industries, producers with high operating expense ratios or those facing materials shortages	Use fewer materials, less energy and less water; minimize waste
Carbon neutrality	Lowers greenhouse gas emissions, minimizes exposure to reporting requirements, carbon taxes and bad PR	Large emitters, regulated industries, businesses reliant on coal or oil for energy	Use less energy in production and during lifetime use; if possible, use clean energy sources
Health and safety	Minimizes exposures to regulation, potential liability and bad PR	Users of chemicals, heavy metals and regulated materials	Use non-toxic inputs, minimize pollution

A more detailed set of outcomes and strategies is provided in the Appendix. Business leaders can review the list for product-appropriate outcomes that will advance corporate objectives. For example, if a manufacturer is facing rising energy costs at its plant, it may look for ways to use hot water more efficiently. If a competitor has garnered attention for its new energy-efficient model, the manufacturer may wish to create a carbon-neutral offering. If the product is intended for infants, the manufacturer may consider using only materials that are certified to be free of phthalates and bisphenol A, and then market these products to health-conscious parents.

Optimizing for Outcomes with Digital Prototyping

Once the desired outcome is selected (such as lowering energy use during production by 20 percent), the design team can pick a strategy (reduce the number of heat-treating operations) and analyze the inputs and process steps to understand the impact of each on the outcome. The team can then build a 3D virtual model to facilitate its analysis and decision-making. As the model develops it becomes a more accurate digital prototype of the product, reflecting the material attributes such as weight, strength and recycled content, and process attributes such as energy intensity and water consumption.

The team can experiment with alternatives that might achieve the desired goal. In this example, the team might consider using designs that can take advantage of selective induction hardening processes rather than bulk heat-treating. Experimenting with different scenarios will reveal the feasible and cost-effective options.

As the product design evolves from concept through engineering and on to production, it can be tested, modified and optimized to achieve the desired outcome. Sharing a digital model among multiple team members throughout the process helps keep them aligned and focused on achieving the intended result.

Product outcomes and strategies will vary widely according to the type of business, constraints and market opportunities. Examples might include:

- Facilitating quick disassembly and recycling by using a single bolt to assemble the back to an office chair frame; [15]
- Substituting recycled plastic for virgin lumber in playground equipment; [16]
- Lowering energy use by 50 percent and eliminating the need for oil and lubricants by creating a gearless elevator hoist, [17] and
- Enabling fast, cost-effective remanufacturing by using only standard, interchangeable parts.[18]

Image courtesy of Big Toys, Inc.

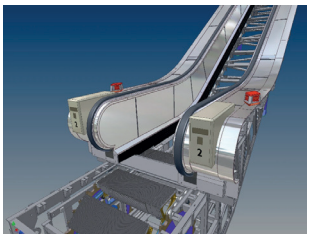
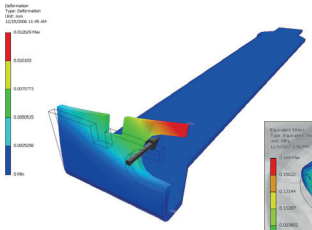
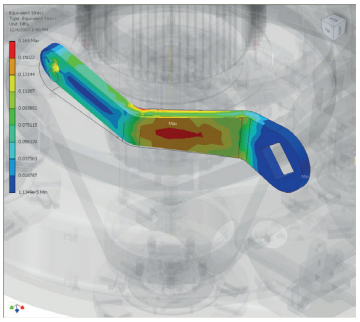


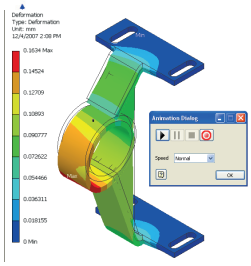
Image courtesy of Kone

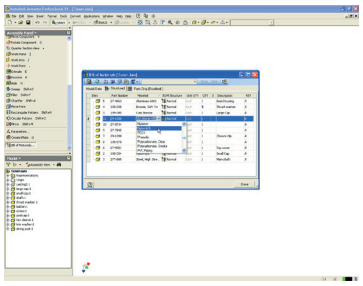
Regardless of the specific sustainable outcome and strategy selected, a digital prototype will save the design team time and money as it analyzes and tests alternative options. In many cases, the digital prototype will be able to predict the impact of the proposed change on the product's characteristics and the energy consumed during its manufacture. Armed with such data, the design team can quickly and cost-effectively experiment with different material and process variables until it discovers the optimal combination. Multiple options for the same product can be saved at any stage, from concept through manufacturing, allowing the team to pursue multiple strategies in parallel. If the market or regulatory environment changes, the product can quickly be optimized to meet the latest conditions. The digital prototype reduces risk by keeping options open as long as needed.





The digital model can also be used to simulate stress and performance tests to facilitate compliance with safety standards. Rather than building physical prototypes, the optimized design can be tested and broken virtually before spending a dollar on materials or labor.





If a manufacturer chooses to optimize its product for disassembly, the digital prototype simplifies the analysis. By using the assembly design features in Inventor software, the design team can examine the parts and the process needed to dismantle a product and repurpose its materials. Quick disassembly is a critical product feature for companies interested in establishing an ongoing relationship with customers via a service and subscription model. It also simplifies recycling and resource recovery and lowers labor costs.

After the product is in production, the digital prototype assists with regulatory compliance and certification requirements. Data management of bills of material simplifies compliance with either mandatory or voluntary frameworks.

Digital prototyping offers even greater promise for the future. Autodesk indicates that it currently plans to expand education and tools to help customers adopt sustainable design techniques and choose among sustainable design alternatives. Design software will become an increasingly important tool in efforts to improve the sustainability of manufacturers, by allowing designers to make better decisions in the early stages of product development, when they are most effective. Future product capabilities may make it even easier and faster for manufacturers to design products that are resource-efficient, carbon neutral, healthy and safe. [19]

[15] Haworth, Inc.'s Zody chair, http://www.haworth.com.

[16] BigToys, http://www.bigtoys.com.

[17] KONE Corporation, http://www.kone.com.

[18] Caterpillar, http://www.cat.com.

[19] Autodesk reserves the right to alter product offerings and specifications at any time without notice, and is not responsible for typographical or graphical errors that may appear in this document.

Conclusion

Sustainability is here to stay. The business world is undergoing a permanent change, and smart business leaders will build sustainability into their business model. In addition to the environmental benefits, sustainability offers great financial, competitive and other business rewards that give manufacturers a competitive edge in a global design market.

- Reduce material and energy costs
- Limit waste
- Limit potential liability
- Meet regulatory and certification requirements

Manufacturers are increasingly choosing to improve the sustainability of their business operations, production processes and product designs to drive profitability and growth. A sustainable design methodology and digital prototyping software are both essential tools to help designers develop products meet one or more business-oriented, environmental outcomes.

The time to act is now.

Request More Information

To learn more about Autodesk's approach to Digital Prototyping, visit **www.autodesk.co.au/beyond3d** today.

Appendix

The following tables provide examples of sustainable product outcomes and strategies under the broad headings of resource efficiency, carbon neutrality and health and safety. Options are suggested in the areas of materials, energy, water and waste. Each might serve as the starting point for a design team looking for ways to lower the environmental impact of a product, consistent with the company's business priorities.

Resource Efficiency

Materials	Energy	Water	Waste
Appropriate—use only what's needed to meet safety and performance standards	**Efficient**—use the minimum energy necessary during production; run equipment at full capacity as much as possible	**Efficient**—use the minimum necessary during production and the useful life of the product	**Efficient**—streamline production processes to minimize defective units, production overruns and scrap
Recycled—use recycled feedstocks to support the market and ensure continuous supply	**Saving**—use the minimum energy necessary during the product's useful life	**Reclaimed**—use recaptured water during production whenever possible	**Durable**—design for longevity and reusability (avoid disposable or single use products)
Recyclable—avoid fusing parts or applying finishes that interfere with recycling and resource reclamation	**Efficient**—use a low- or no-energy recycling process at end of life (avoid steam cleaning, high-temperature melting if possible)	**Reuse**—capture, treat (as needed) and reuse water for production as many times as possible before discarding	**Recyclable**—use fewer, standard parts; simplify disassembly to ease resource reclamation
Renewable—use fast-growing natural substances (e.g. bamboo) whenever feasible			**Minimal packaging**—ideally, use none, but if necessary, make it minimal, recycled, reusable and returnable

Carbon Neutrality

Materials	Energy	Water	Waste
Low-carbon—use bio-based alternatives to oil-based whenever possible (but avoid virgin wood unless FSC-certified)	**Green power**—rely on clean power from utilities or use self-generated power (solar, wind, geothermal, biofuels) at factory	**Efficient**—minimize the use of hot water during production and the product's useful life (since hot water is very energy-intensive)	**Reuse**—find another manufacturer that can use bio-based scrap
Lightweight—minimize weight to reduce the energy needed to ship materials and finished goods	**Green power**—design the product so it can generate its own power (e.g. solar-powered charger) or use a clean energy source		**Compost**—compost any unusable bio-based scrap to prevent landfill gases caused by decomposition
Local—source locally to reduce the energy needed to ship materials and components to factory			

Health And Safety

Materials	Energy	Water	Waste
Non-toxic—avoid or minimize the use of hazardous or potentially hazardous materials	**Green power**—rely on clean power from utilities or use self-generated power (solar, wind, geothermal, biofuels) at factory to lower toxic emissions from power plants	**Minimal**—avoid or limit the use of chemicals during production that can contaminate waterways	**Capture**—install high-grade filters and scrubbers to limit airborne particles produced by manufacturing
Safe—choose natural materials that have proven harmless over time	**Green power**—design the product to generate its own energy (e.g. solar-powered charger) or use a clean energy source		**Recycle**—if chemicals must be used in production, capture and recycle them for on-site or off-site reuse

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