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Chapter 5

Research and Development

Growing public pressures, stricter enforcement of environmental laws, costly cleanup costs, limited resources, and less disposal options are creating the need for research and development (R&D) departments to rethink plans, policies, and procedures. The unique nature of R&D activities makes planning sustainable efforts extremely difficult. This chapter discusses several concepts (cradle to cradle, biomimicry, life cycle assessment, and crowdsourcing) that facilitate meaningful R&D for sustainability.

5.1 Cradle to Cradle

Products and processes have historically been designed for cradle to grave. That is, design has only considered the product from the point of manufacture to disposal. With growing awareness of environmental impacts and companies' tendency to externalize costs, there has been a shift in thinking about design in terms of **cradle to cradle**¹, or from the point of acquisition of raw materials to the point of recycle and reuse. McDonough and Braungart (2002). Cradle to cradle design requires a shift in thinking about traditional manufacturing, recycling, and environmentalism. Cradle to cradle design encourages us not to choose the least environmentally damaging approach but rather to create and design a better approach. Cradle to cradle design encourages the integration of nature into the design process with a goal of zero waste. Products and processes integrating this design philosophy can receive Cradle to Cradle certification. McDonough Braungart Design Chemistry, LLC (2008).

1. A way of thinking about manufacturing design from the acquisition of raw materials to the point of recycle and reuse, with a goal of zero waste.

5.2 Biomimicry

Biomimicry² is an innovative method that searches for sustainable solutions by imitating features naturally found in the environment into the design of products. Using biomimicry, sustainable businesses can look at nature in new ways to understand how it can be used to help solve problems. Nature can be seen in three different perspectives: nature as model, nature as measure, and nature as mentor. Benyus (1997). Nature as model implies the emulation of forms, processes, or systems in product design. Nature as measure implies the evaluation of what is being designed against criteria of nature to see if current methods are as efficient as those from nature. Nature as mentor means creating a bond or relationship with nature, treating nature as a partner and teacher rather than just a place for resource removal. Benyus (1997).

Many industries have benefited from biomimicry. In the transportation industry, the fastest train in the world, the Shinkansen Bullet Train of the Japan Railways Group, incorporated biomimicry design methods into its revised design. With the initial design of the train, a loud noise was produced when the bullet train emerged from a tunnel. Designers redesigned the nose of the train after the beak of a kingfisher, which dives into water to catch fish. Not only did the modification create a quieter train, but it also resulted in less electricity usage and faster travel time. Biomimicry Institute (2009). This is an excellent example of utilizing nature to improve engineering.

Another example is GreenShield, a fabric finish made by G3i, which provides the same water and stain repellency as conventional fabric finishes with 8 times fewer harmful chemicals. Biomimicry Institute (2009). The innovation was developed from the water repellency of the leaves of a lotus plant. The plant's surface texture traps air so that water droplets float and slide off cleanly while removing the dirt.

After studying the flippers, fins, and tails of whales, dolphins, and sharks, the company WhalePower applied biomimicry to design a far more efficient wind turbine blade with less drag, increased lift, and delayed stall. The company expects to apply its design to fan blades of all types to gain up to 20% increased efficiencies and quieter operations. WhalePower (n.d.).

2. An innovative method that seeks out sustainable solutions by imitating features found in the environment and using them in product design.

The air conditioning system of Eastgate Building, an office building in Zimbabwe, was modeled from self-cooling mounds made by termites. The building uses 90% less energy than conventional buildings of the same size, and the owners have been able to spend \$3.5 million less on air-conditioning costs. Biomimicry Institute (2009).

These are but a few examples of the many improvements in design that have been brought about through biomimicry, or nature-inspired design. Sustainable businesses can find workshops, research reports, biological consulting, field excursions, and other resource information from the Biomimicry Guild, an environmental consultation firm, and from the Biomimicry Institution, a nonprofit advocacy group. The Institute has developed an online interactive resource, AskNature.org, Retrieved March 23, 2009, from <http://www.asknature.org> which allows users to pose a problem, and feedback is provided in the form of multiple ideas or examples from nature that might be useful in solving the problem.

5.3 Life Cycle Analysis

As environmental awareness becomes more prevalent, businesses are assessing how their activities affect the environment. The environmental performance of products and processes has become a key issue, which is why some companies are investigating ways to minimize effects on the environment. **Life cycle analysis (LCA, sometimes referred to as life cycle assessment)**³ measures the environmental impact of specific products or processes from cradle to grave. Cradle to grave begins with the gathering of raw materials from the earth to create the product and ends at the point of materials disposal, recycle, or reuse (although LCA uses the term cradle to grave, recycle and reuse scenarios can be built into the analysis for a more accurate cradle to cradle analysis). LCA provides a snapshot in time of a specific product from a specific manufacturer, and it may be difficult to generalize findings. However, LCA is a useful tool for making product and process decisions that consider environmental criteria. The benefit of LCA is that businesses can identify the most effective improvements to reduce cumulative environmental impacts resulting from all stages in the product life cycle, often including upstream and downstream impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). LCA is widely used for different purposes by different groups: environmental groups use it to inform consumers on what to buy, legislators use it for creating rules and regulations, and manufacturers use it as they seek to improve design and production standards. Less commonly used methods for environmental comparisons include value–impact assessments, environmental option assessments, and impact analysis matrices.

The LCA process is a systematic phased set of stages and is comprised of four components: goal definition and scoping, inventory analysis, impact assessment, and interpretation. The first stage is goal definition and scoping, which identifies the purpose of the analysis and the context in which the assessment will be conducted. In defining the scope of the LCA, it is important to define the system boundaries. The system boundaries can affect the outcomes of an LCA. Therefore, when comparing multiple products, such as plastic versus corn-based disposable cutlery, it is essential to ensure that the same system boundaries are used to examine both. A functional unit needs to be selected, such as a box of cereal, or a bar of soap, or a ton of grain. The definition of the boundaries should include where the material is extracted (the cradle) and what is the final disposal point for the product (the grave).

The next stage is the inventory analysis where data is collected related to energy, water, and materials usage. LCA includes an analysis of what has been used from the

3. A measure of the environmental impact of specific products or processes from the cradle (the gathering of raw earth materials to create a product) to the grave (the point of material disposal, recycling, or reuse). Also referred to as life cycle assessment.

environment, such as raw materials, and what has been released into the environment, such as GHG emissions, solid waste disposal, and wastewater discharges. When moving to the inventory analysis stage, sustainable companies find it much easier to envision the system boundaries for data collection by developing a model of the life cycle or a flow diagram. A flow diagram is a map depicting inputs and outputs within the system boundaries. The diagram allows the investigator to break down the system into a set of subsystems that represent particular phases of the life cycle and shows linkages across these phases. Bhat (1996). For example, the flow chart may include raw material extraction, raw material processing, transportation, manufacture, production fabrication, filling and packaging, assembly, distribution, use, reuse, maintenance, recycle, and waste disposal. The focus of the inventory analysis is data collection of the raw material and energy consumption and emissions to air, water, and land. Data can be collected from various sources.

Suppliers of materials and energy as well as consultants specializing in sustainability can provide valuable information. Other sources that can provide information are government and industrial databases, government reports, existing LCA reports, and laboratory test data. LCA, though very valuable to sustainable businesses, is complex and labor intensive. Software is available to eliminate the need to conduct complex calculations. A sample of LCA software tools can be found at the following Web site: http://www.life-cycle.org/?page_id=125. Gloria (2009).

The two final stages, life cycle impact analysis and interpretation, evaluate the effects of resources and emissions identified in the previous stage. The third stage uses the findings of the inventory analysis to conduct an impact analysis that considers the consequential effects on population and ecology. Impact analysis provides quantifiable impact information on such issues as environmental and human health, resource depletion, and social welfare. The steps that have been identified with the impact analysis stage are identifying relevant environment impact categories, for example, global warming or acidification; classification or classifying carbon dioxide in relation to global warming; characterization or modeling the potential impact of carbon dioxide on global warming; describing impacts in ways for comparison; sorting and ranking indicators; weighting the most important impacts; and evaluating the results. Scientific Applications International Corporation (2006). The final stage is to interpret the findings from the previous stages to make informed decisions for products and processes. Scientific Applications International Corporation (2006).

The greatest benefit of an LCA is that it allows scientific comparison of products or processes in order to determine the most environmentally friendly option from cradle to grave. This scientific evidence may or may not support our beliefs about the best choice among options (see [Note 5.4 "Test Your Knowledge"](#)). However, the

limitations of LCA studies should be understood when interpreting results. LCA studies are a static profile capturing the qualities of a specific product at that moment in time. The studies are constrained by the product (or process) selected, the manufacturer selected, its manufacturing practices, its supply chain practices, and the other boundaries of scope defined at the onset of the study. In addition, there are numerous approaches to the use of LCA, which further restrict comparison of studies. For example, depending on the purpose of the LCA, researchers may opt to use economic input-output LCA, screening LCA, process LCA, hybrid LCA, full-product LCA, financial LCA, life cycle energy analysis, or other specific approaches. As such, there exists much controversy over LCA study results as an indication of eco-friendliness. Narayan and Patel (n.d.). Furthermore, there is criticism that LCA studies only focus on environmental aspects and neglect other aspects of sustainability. While not a perfect method, LCA is the best model that exists for considering the environmental impact of products, processes, and services.

TEST YOUR KNOWLEDGE

Based on the results of life cycle analysis (LCA) studies,* which is the more environmentally friendly choice?

1. **Paper or Styrofoam cup?** LCA research shows production of Styrofoam is less energy and water intensive than paper cups and that production of paper cups creates more greenhouse gas (GHG) emissions. Haag, Maloney, and Ward (2006). The conclusion: Styrofoam is better from an environmental standpoint, but neither is ideal. Haag et al. (2006).
2. **Stainless steel coffee mug or ceramic mug or Styrofoam cup?** LCA research shows a reusable ceramic mug is more environmentally friendly than Styrofoam *as long as it is used at least 46 times* (that's 46 cups of coffee!). Paster (2006). The LCA also shows that a stainless steel mug must be used at least 396 times to be more environmentally friendly than Styrofoam. Paster (2006).
3. **Biodegradable to-go food containers or Styrofoam?** LCA research shows biodegradable bioplastic containers made from corn or other agricultural products create more GHG emissions than Styrofoam. Athena Sustainable Materials Institute (2006).
4. **Bioplastic disposable cutlery or plastic?** LCA research shows that bioplastic products made from corn or other agricultural products (such as PLA or PHA) require more energy and produce more GHG emissions in manufacturing than do petroleum-based plastic cutlery. Gerngross and Slater (2000).
5. **Biodegradable or plastic or paper bags?** LCA research shows that plastic bags produce the least environmental impact in manufacturing, transportation, and recycling. Lilienfeld (2007).

* Since the time of the studies mentioned here, products and processes may have improved, thus impacting the results if another LCA study were to be conducted today. Updated LCA studies are needed.

As an example, an LCA of PLA (a corn-based bioplastic manufactured by Dow Chemicals's NatureWorks, LLC) versus plastic found that the manufacture of plastic was less energy intensive, thus emitting fewer greenhouse gases during the manufacturing process, and that the plastic manufacturing process required less water. Therefore, the conclusion was that plastic was a better choice than PLA from an environmental impact standpoint. However, when the manufacturer of PLA, NatureWorks LLC, began purchasing wind power carbon offsets in 2006, the company's LCA studies suggested that NatureWorks's PLA was now the better choice from an environmental impact standpoint. Vink (2007). Others have

disagreed with these results based on the argument that the purchase of wind power carbon offsets, or the investment in another company's wind power project, does not bring the wind power to the NatureWorks manufacturing facility and, as such, does not reduce the intensity of the electricity consumption during the PLA manufacturing process. Athena Institute (2006). As this example demonstrates, LCA studies compare a specific product and determines its impact at that point in time, given the manufacturer, its various processes, and the boundaries defined for the study. This limits generalization of the findings to similar products by other manufacturers.

5.4 Crowdsourcing

Organizations have long used techniques such as brainstorming, the Delphi technique, and quality circles for employees and managers to generate creative solutions to problems. **Crowdsourcing**⁴Howe (2006). is a similar idea on a larger scale using the Web to reach a larger set of problem solvers. Problems are made available via the Internet in the form of an open call for solutions. Participants (the crowd) may be customers, suppliers, employees, member communities, or simply the general public. The participants suggest solutions to the problem, discuss their merits or disadvantages, and select favorite choices. Participants can be motivated to do so through awards, recognition, or financial compensation. Participants are potential end users of the product and are generally willing to provide ideas and solutions from that aspect.

Sustainable businesses can benefit from crowdsourcing, which also has been referred to as community-based design, as a substitute for in-house R&D to reduce overhead and staffing expenses. Businesses can create their own online crowdsourcing site or they can utilize one of the many links that are currently available. Online discussion and voting from the community at large provides results similar to company-driven marketing research. Companies can obtain feedback, ideas, and solutions from a wider range of talent, which can conceivably develop better products with faster time to market and at lower costs.

As an example, InnoCentive provides outsource research functions to a variety of disciplines such as life sciences, computer science, business and entrepreneurship, engineering, and chemistry. Sustainable organizations can register with InnoCentive as solution seekers, while individuals can register as solvers. Organizations post a dilemma or problem for which they are seeking a solution, and the open community of solvers is available to offer suggestions and solutions.

For example, SunNight Solar developed solar-powered flashlights for use in developing countries and areas without electricity. The initial design provided task lighting, but the goal was to create another design to replace kerosene lanterns (a safety and environmental hazard) and to illuminate entire rooms. After several failed design attempts, SunNight Solar CEO Mark Bent turned to InnoCentive and put forth the design challenge to InnoCentive's social network of over 140,000 solvers. The challenge was solved and the new SL-2 light, or Super BOGO, was sent into production.

4. A process of posting design-based problems on the Internet and openly querying participants for ideas and solutions. Sometimes referred to as community-based design.

Other crowdsourcing venues that outsource for a broad range of industries or disciplines include Innovation Exchange, NineSigma, Fellowforce, and Yet2.com. Retrieved March 23, 2009, from <http://www.yet2.com>
CrowdSPRING Retrieved March 26, 2009, from <http://www.crowdspring.com> focuses on contributions for logo design, business card design, graphic design, Web site design, and photography. Amazon created a platform called the Amazon Mechanical Turk Retrieved March 26, 2009, from <https://www.mturk.com/mturk/welcome> on which tasks called “HITS” (Human Intelligence Tasks) can be made public for people to work on and receive compensation.

As with other functions of the business, sustainability brings new ways of thinking to the task of R&D. From the way products are designed to the way research is conducted and problems are solved, sustainability challenges our old mindsets.