CHAPTER 5

Design for Sustainability—Collectively Transforming Systems and Process

> Design is the first signal of human intention.
>
> Bill McDonough, in the documentary,
> The Next Industrial Revolution

Where can you find evidence of substantial change and the impacts of sustainability on products, processes, and supply chains? Design, and the use of environmental AND social metrics have together culminated in new insight, cost savings, impact reduction, and differentiation as a result of leveraging sustainability for operations and supply chains. Examples include:

- The DuPont mission is "sustainable growth"—creating shareholder and societal value while reducing the company's footprint throughout the value chain. DuPont businesses leverage the role of Life Cycle Assessment in setting the goals, in developing innovative solutions for sustainable product and process design, in monitoring progress toward goals, and in stakeholder engagements.
- Timberland conducted an LCA for a leather boot and calculated emissions at all stages of the value chain, including sub-suppliers like the cattle industry that provided the leather. Surprisingly, leather use was responsible for most of the emissions, at around 80% of the boot's greenhouse gas burden. Timberland now knows that reducing the amount of leather per boot will shrink its climate-change impact far more than reducing energy use at assembly plants or distribution centers.

- Data from companies such as Trucost enable organizations to identify, measure, and manage the environmental risk associated with their operations, supply chains, and investment portfolios. Quantifying environmental risks and a price for these risks is key to their approach. Entities like this one utilize public and proprietary data in providing a systematic approach to measuring and managing supply chain impacts leveraging data to quantify the environmental costs of suppliers, including carbon, water, waste, and air pollution.
- McKinsey and Co predicts $380 Billion in potential annual net material cost-saving opportunity in the European Union (EU) from adopting "circular" business practices. In this system, value is created by looping products, components, and materials back into the value chain after they fulfill their utility over the life of the product. To realize the full resource productivity opportunity, firms will need to work across circular supply chains, analyze how raw materials are extracted, components produced, products designed, and how return markets are organized, while also considering new business models such as leasing products to customers to retain ownership of materials embedded in the products.[1]

These examples illustrate the new opportunities available from a better understanding of products, processes, and supply chains. In this chapter, we discuss the evolution of design trends, stress the importance of educating management as to the importance of design thinking, and the utilization of well-known stage-gate product design processes. We review our own research regarding the adoption of sustainability practices by different categories of firms (innovators, early adopters, early majority, late majority, and laggards), before discussion what it will take to cross the sustainability chasm to integrate better design into current practices. To help operationalize this integration, we review important frameworks and tools such as Industrial Ecology, LCA, C2C, and The Natural Step, before reviewing opportunities to design with less energy and materials, planning, and project assessment.

Objectives

1. Understand what firms are doing to integrate sustainability into stage-gate new product design processes.
2. See opportunities though a design and systems thinking lens.
3. Review current frameworks and tools of sustainable design.
4. Leverage Design for Sustainability (DfS) to improve product and process efficiency.

Introduction

It's hard to know why Apple made the decision to stop certification of its products by Electronic Product Environmental Assessment Tool (EPEAT), a green computing standard.[2] This important standard moved the product-labeling sector toward more detailed product assessment and was supported by an Executive Order in 2007 requiring all U.S. government agencies to procure 95% EPEAT-registered products. As a result of Apple's actions and the decision to stop utilizing this product standard, whole cities such as San Francisco have blocked Mac purchases.

The reality for Apple and other electronics manufacturers is that there is no single definition of a "green product." The manufacture, use, and disposal of IT products can have a wide range of environmental impacts. Some products may have excellent environmental performance in some dimensions, such as energy efficiency or the absence of toxic materials, but less than excellent performance in other dimensions such as raw material extraction and transportation. Apple has performed LCAs of its products and found that 91% of the GHG emissions associated with its products are traceable to the manufacturing and use phase. It traced just 2% of its GHG emissions to recycling. Some issues with glued-together components of products such as the Macbook Pro will need to revisit design and LCA information to help make decisions regarding product labeling. While this product offering is lighter, and has more power, customers cannot take it apart, and it cannot be upgraded or recycled. These product attributes become order losers for many that have been happy with Mac offerings in the past.

Apple has a history of mixed messages when it comes to sustainability and customer engagement. As of the writing of this book, in the most recent back and forth with customers, Apple's newest laptop, the MacBook Pro with Retina display, has taken a substantially unimpressive reversal in recyclability, which means the product didn't qualify for EPEAT certification. When the news broke, Apple reacted, pulling ALL its computers from the EPEAT program and claiming that customers valued design over sustainability. Customers, including the city of San Francisco, were quick to disagree, and just as quickly as they had reacted, Apple had not only returned to the EPEAT standard but assigned the latest (still not recyclable) laptop an EPEAT gold rating. Apple's strategy could use a closer look at business model alignment, the green capabilities of its products and processes, and key customer engagement. Apple already designs very attractive products, and it appears they have gone astray from earlier "green" product attributes and again need to design sustainability into their products and processes. A design thinking approach to any product or process refers to the methods and processes for investigating ill-defined problems, acquiring information, analyzing, and positing solutions early in the design and planning process.

Within this chapter, we want readers to take a step back from their own processes and look at the world as a designer. With this in mind, we first look at the origins of DfS and well-known stage-gate processes for integrating sustainability metrics and decision criteria into decision-making practices. We review the chapter design architecture of topics (Figure 5.1) while presenting evidence of the growth of DfS, we identify

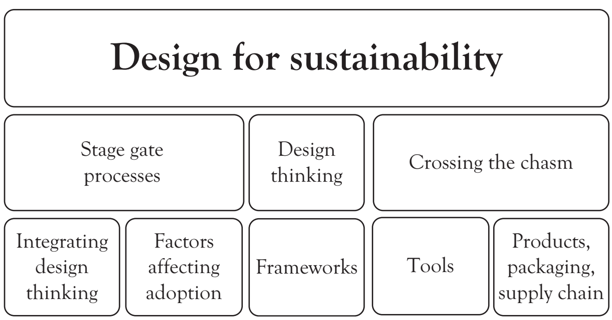


Figure 5.1. The design architecture.

trends that will remain important to operations and supply chain managers, and highlight how firms across industries are crossing a chasm into new territory. By the end of the chapter, we review frameworks and tools available to help enable operations and supply chain professionals to identify sustainability opportunities. Finally, we take a look at metrics and tools before reviewing a step-by-step approach to design practices.

DfS has been applied to developing economies, city planning, architecture, and is defined as "requiring awareness of the full short and long-term consequences of any transformation of the environment. Sustainable design is the conception and realization of environmentally sensitive and responsible expression as a part of the evolving matrix of nature."[3]

As seen in the concepts of JIT lean, TQM, and Time-Based Competition (TBC), waste is any activity or product that consumes resources or creates costs without generating any form of offsetting value stream. We know that managers can minimize waste by changing the way new products are designed. Those firms who include environmental issues in the design process have the opportunity to reduce disposal costs and permit requirements, avoid environmental fines, better utilize raw materials, boost profits, discover new business opportunities, rejuvenate employee morale, and improve the state of the environment.

Ideally, the most appropriate place for considering sustainability issues is in the design phase since the amount of waste generated is a direct consequence of decisions made during product and process design. As it is generally used, the term "Design for Environment" (DfE) is a component of manufacturing and supply chain management and involves making environmental considerations an integral part in the design of a product. The concept of DfE originated from industry's effort to target specific environmental objectives for design engineers to incorporate when creating a new product. DfE basically involves the incorporation of environmental considerations into the design and redesign of products, processes, and technical and management systems. The goals of sustainability can more easily be achieved when environmental issues are identified and resolved during early stages of product and process design, when changes can be made to reduce or eliminate environmental waste.[4]

Most of the research aimed at the development and evaluation of new environmental tools and procedures have been targeted toward the design stage. This emphasis recognizes the importance of DfE to the overall success of waste reduction and elimination. We now realize that product design, while actually responsible for a relatively small percentage (approx. 5–10%) of the total costs, has a significant impact on the actual costs incurred within the system. Some estimate that up to 85% of life cycle costs are committed by the end of the preliminary design stages. For thirty years now, we have known that at least 50% of the costs for a class of mature products are design-determined and that up to 70% of costs are affected by manufacturing process decisions.

When viewed in this light, it is expected that more managers will be interested in the implementation and use of DfS procedures and tools. Managers will also want to look at DfS issues during the redesign or re-engineering of a product or process. Redesign and re-engineering typically occur during the maturity or decline phase of the product life cycle, however the time in which a firm is rethinking a product or process is not the only opportunity for DfS practices. After all, DfS involves the identification and elimination of in-process waste streams before they actually occur. However, for most firms, DfS has not achieved the same degree of acceptance as have JIT, TQM, and TBC. Our research in this area has shown that the level of acceptance of sustainability practices and principles remains very uneven. Some firms such as 3M, Bayer Material Sciences, Baxter, Dow Chemical, DuPont, Herman Miller, Intel, Interfaces, L'Oreal, P&G, and Timberland, to name a few, have tried to incorporate these concerns into the design process and evaluate product performance not only in terms of costs and profit but also in terms of environmental outcomes. For other firms, DfS remains a perceived constraint—as something that adversely affects the ability of the firm to deliver better products to the marketplace.

Product designers need to understand sustainability opportunities and be able to influence process design. Instead, top management focus on regulatory constraints, the slow corporate decision-making process, and cost. Engineering-based design evaluations have long been cited as obstructing environmental issues from being an integral part of product design.[5] As you will see, these necessary changes are already happening.

Product Design and DfS

The product design process is one of the major tasks for any firm, responsible for two major types of design activities: (a) new product design and development, (b) process design and development. Both products and processes designs are closely interrelated and greatly influence each other while simultaneously impacting the environment. Both aspects must be considered to ensure that the firm has developed and implemented effective and efficient designs and processes. These design activities (Figure 5.2), in general, present opportunities for firms to find solutions to environmental issues and even social issues. These two design activities, when combined, shape the scope of the transformation process by determining the types of inputs required and outputs created. Inputs involve substitution of lesser hazardous alternatives for previously hazardous materials. Some outputs are desirable (e.g., cars built) while others, such as pollution and waste, are not.

The product development process embodies all of the steps necessary to take the product from concept to full production. Recently, this process has undergone extensive revision and rethinking due to increased market pressures to reduce the total cycle lead time (from concept to full production), reduce cost, enhance product flexibility, improve product quality, and leverage new tools such as LCA and information. These pressures are some

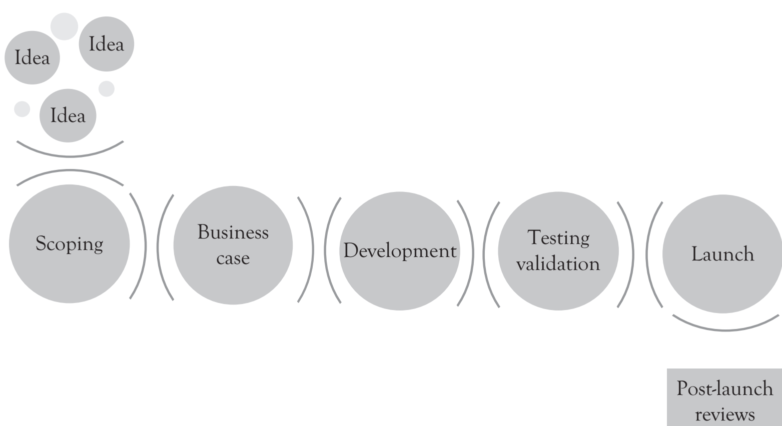


Figure 5.2. Cooper's stage-gate new product development model.

of the same forces that impact prior developments such as TQM, JIT, TBC, and mass customization.

To reduce total cycle lead time, managers have turned to the development of processes characterized by the use of multifunctional teams and close interaction of the team members over the period of the initial design. This multifunctional teaming and interaction is also integrative in terms of the breadth of the manufacturing system. Examples can be seen in the consideration of not only issues of design but also issues pertaining to manufacturing planning and execution. This reorganization of the design and delivery process has been referred to by such names as simultaneous engineering and concurrent engineering.

One can envision the process (i.e., product/process design and delivery system) as consisting of linked stages: discovery and idea generation; scoping; building the business case; development; testing and validation, launch, and finally post-launch review.[6] Between each stage is a decision-making gate. The go/no-go gates provide an organized approach to assessment of easier-to-manage innovation and new product design processes. In all stages of the new product development (NPD) process, environmental and sustainability factors must be considered in addition to all other objectives and issues. Furthermore, one function or group no longer manages each activity in isolation. Rather, there is integration of multiple groups or stakeholders, both internally, with other functions, and externally with stakeholders, customers, and suppliers. In the earlier stages of development process, meeting the needs of stakeholders "such as key customers and regulators" is important. In the later stages of this stage-gate process, working with special interest groups and third-party endorsement of products becomes important.

The stage-gate model processes include:

The *discovery stage* contains prework designed to discover opportunities and to generate new ideas. The current focus is on innovation and design thinking, understanding the needs of key customers while leveraging technology, transportation, and closed-loop supply chains.

Scoping is a preliminary analysis of each project. It provides inexpensive information through basic research to enable narrowing the number of projects. This stage can be a first screen for environmental AND social attributes using known standards, and simple checksheet approaches to identifying potential attributes.

Building the business case is a more detailed analysis by primary marketing and technical research. The business case must include the product definition, justification, and a project plan. Here are opportunities to identify LCA impacts and alternative materials and processes, financial performance projections and top line growth, SVA, sustainable performance review of a supply base, and supply chain analysis and optimization considering variables such as GHG emissions, timing and modes of transportation within given markets.

Development is a detailed design and development of the product along with some preliminary product tests. At this time, a production plan and a market launch plan are developed, exploration of available environmental and sustainable certifications such as C2C, product labeling, Environmental Product Disclosures (EPDs), and applicable ISO certifications.

Testing and validation take a deeper dive into product tests in the marketplace, the lab, and the manufacturing process. Supplier auditing of social AND environmental performance and measurement of product/process impacts such as GHG emissions.

Launch is the beginning of full production, marketing, (if possible, ecolabeling) and selling. Market launch, production and operations, distribution, quality assurance, and reverse logistics should include post-launch reviews and updated information for corporate sustainability reporting aligned with the GRI, CDP, and information for stakeholder inquiry such as socially responsible investors and fund analysts.

The stage-gate model is generalizable and with minimal modification, accommodates environmental and social considerations into each gate and screening process. Of course, it will be necessary to drill down into more firm specific detail of the sub activities to provide insight and operational instructions for any innovation team. Our own work with firms taking this approach simply starts early in the discovery and scoping stages with a screen for environmental and social performance indicators. A simple checksheet goes a long way toward engaging others in how and why financial, AND environmental, AND social performance can be considered early in any product development process.

There are a number of advantages to using the stage-gate model for product development, which typically result from its ability to identify problems and assess progress before the project's conclusion. Poor projects can be quickly flagged and rejected by disciplined use of the model and gated processes. When using the stage-gate model on a large project, the process can help reduce complexity of what could be a large and limiting innovation process into a straightforward rule-based approach. When a stage-gate model incorporates cost and fiscal analysis tools such as net present value (NPV), and Economic Value Added (EVA), management can project quantitative information regarding the feasibility of developing potential product ideas. In the not too distant future, this model will also include SVA. Finally, the stage-gate process includes an opportunity to validate the business case by a project's executive sponsors. Other advantages include but are not limited to:

- Well-organized innovation process as a source of competitive advantage
- Prevents poor products in early stages and helps to redirect them
- Accelerated product development, a necessity of shorter product life cycles
- Increases success of new products
- Breaks down complex innovation process within large organizations into smaller pieces
- Provides overview, prioritization, and focus
- Integration and market orientation
- Cross functionality, utilizing input and participation of employees from various functions
- Can be combined with various performance metrics such as the SVA concept

One issue with the stage-gate process is the potential for structural organization to interfere with creativity, as overly structured processes may cause creativity to be reduced in importance. Other limitations include:

- This is set up as a sequential approach to innovation, yet some believe innovation should be organic and organized in parallel with feedback loops
- Tensions exist between organizing and creativity. Both are important to innovation.
- The stage-gate process needs to be modified to include a top-down link to the business strategy if applied to non product development projects

The end of the product development process creates several important outcomes, such as the design and introduction of the product, the determination of the types and quantities of materials used, and various processing characteristics (i.e., equipment needed, transportation optimization, closed-loop supply chains, and intermodal options). When taken together, the product design process sets in place the material and capacity requirements, establishes the cost and performance traits of the product, and determines the types and timing of waste streams created and when these waste streams will be created.

The design activities are strongly cross functional in nature. That is, to be successful from both a corporate and marketing perspective, the product design activities must consider the perspectives of multiple parties and stakeholders.[7] Included are internal areas such as marketing, product engineering, finance, manufacturing, production and inventory control, accounting, manufacturing engineering, quality assurance, top management, and external stakeholders such as stockholders, suppliers, government, competitors, special interest groups, the environment, and the customer.

The importance of the gates should not be overlooked. The role of the gate is to ensure that all of the major concerns, objectives, and issues present in the preceding stage have been addressed before permitting the process to continue to the next stage. At these gates, different factors affect sustainability initiatives such as formal information systems, the presence of a green corporate culture; and the use of different tools, metrics, and available options for energy reduction and waste minimization. During these decision-making times between stages, management has the opportunity to generate new practices from environmental, social, and sustainability issues that were formerly viewed as obstacles, but now become opportunities for innovative firms looking for competitive advantage.

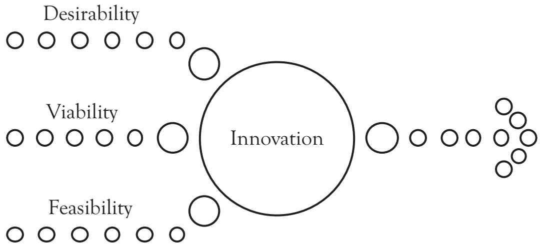
While gates are critical to the innovation process, they do not provide insight as to the creation of new ideas and what is typically found within Research and Design (R&D) functions. To better understand what the innovation creation process may look like, we next draw from the design thinking paradigm to help focus on one component of the business model, key customers.

Design Thinking: Reinvent Products, Processes, and Supply Chains for Customers

> Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success.
>
> Tim Brown, President and CEO of IDEO

Design thinking refers to the methods for investigating ill-defined problems, acquiring information, analyzing, and proposing solutions in the planning and design fields. It is generally considered the ability to understand the context of a problem, creativity in the generation of insights, and rationality to fit solutions to the context. In recent years, design thinking has become a growing part of design and engineering practice, as well as business and management. Its broader use in creative thinking and action learning is having an increasing influence on contemporary education across disciplines. The IDEO approach is currently being used by Duquesne University (Pittsburgh, PA) for teaching and applying design activities within its MBA Sustainability program. In this respect, it is similar to systems thinking in understanding and solving problems.

The design process is what puts design thinking into action. It's a structured ethnographic approach to generating and improving ideas. Its phased approach helps to navigate the development from identifying a design challenge to finding and developing a solution. It's a human centered approach that relies on your ability to be intuitive, to interpret what you observe, and to develop ideas that are emotionally meaningful to those



The innovation design process and its major inputs.

customers you are designing for. The design process consists of discovery, interpretation, ideation, experimentation, and evolution. The result of the process should be: innovative products, processes and services found at the confluence of viability, desirability, and feasibility. For those utilizing design thinking, this approach translates into new, innovative avenues for growth that are grounded in business viability and market desirability.

Currently, there is momentum to create awareness about design thinking not only among designers and other professions, but instead by teaching design thinking in both industry and higher education. The premise is that by knowing about the process and the methods that designers use to ideate, and by understanding how designers approach problems to try to solve them, individuals and businesses and business students coming into the workforce will be better able to connect with and invigorate their ideation processes in order to take innovation to a higher level. The goal is to create a competitive advantage in today's global economy and interconnected supply chains.

How Firms Integrate Sustainability and Design: Crossing the Chasm to Design Sustainable Solutions

To better understand the integration of sustainability into design processes, we draw from a modified version of Moore's (1991) Technology Adoption Life Cycle model.[8] This model has five categories of firms: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards (see Figure 5.2). We see these same categories of firms in our own research and find generalizable attributes of these firms within their different approaches to sustainability and DfS.

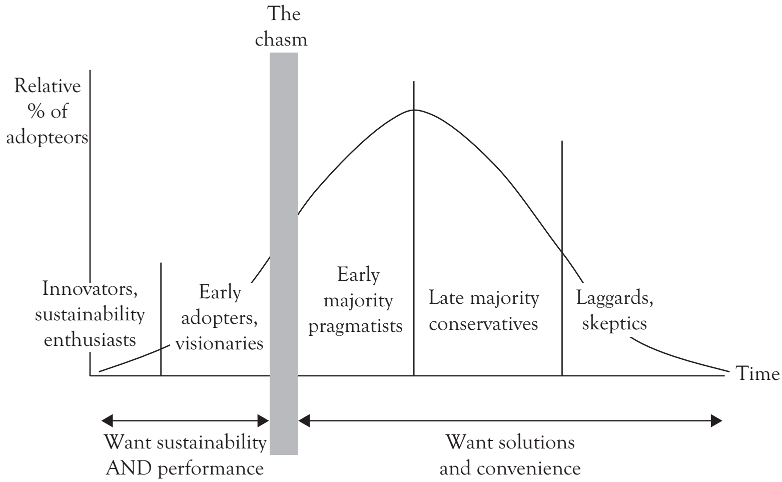


Figure 5.2. Sustainability adoption life cycle.

Source: Modified from Sroufe et al. (2000).

An interesting aspect of Moore's model is the identification of gaps between the categories of firms. These gaps are defined as the amount, or the level of resistance that must be overcome before the group will accept the innovation. With slight modification to fit DfS practices, the gaps signify the difficulties firms, and industries may have with sustainability. The largest gap, the "chasm," separates the Early Adopters from the Early Majority. This chasm is important because the acceptance of sustainability initiatives, amount of time, and resources allocated, type of culture necessary, presence of tools or measures available, and sustainability options explored are vastly different on either side. The gaps between the other categories of firms are not as clear, and do not impact the acceptance of sustainability initiatives as strongly as the chasm. The chasm can be described in what the Early Adopter is pursuing as firms to the left of the chasm are perceived *change agents* with a competitive advantage. The chasm is a gap between different levels of sustainability and DfS practices.

To understand where your own firm may stand or to help identify other firms within a given industry spectrum, we offer the following attributes of each category of firms.

The *innovators* pursue new sustainability management techniques aggressively because unique environmental resources are central to their manufacturing process. These firms may have integrated sustainability in the past because it was right for them given the cross-functional culture, ability to measure performance on multiple dimensions, and business environment they faced. Sustainability and innovation are considered part of the formal corporate culture. Innovators promote their green culture, market "green" or "eco-labeled" products, and seek new technology for specialized information, pollution prevention, more effective public relations programs, frequent auditing and reporting, and frequent management reviews and policy improvements. These firms develop an integrated and formal DfS process in order to have a unique resource (e.g., management and decision support systems) and specialized information to aid in decision making. They find that enhanced financial performance and competitive advantage can come from the design process. There are not many innovators, but their success is key, because their endorsements reassure other firms that new environmental initiatives do in fact work.

A commonly used example of an innovator is the General Electric Company (GE). In 2005, GE launched Ecomagination based on four commitments: (a) double the investment in R&D for cleaner technologies; (b) increase revenues from Ecomagination products; (c) reduce GHG emissions and improve the energy efficiency of GE's operations; and (d) keep the public informed. These commitments represent ambitious goals for GE and reflect the broader challenges their customers and society face. Drawing on their global capabilities, strengths in technology and knowledge of markets around the world give GE the ability to build a broad portfolio of innovative solutions to a range of energy and environmental challenges. In this context, GE Global Research has formed an Ecoassessment Center of Excellence that provides focused expertise in LCA, end of life and transportation of materials in the environment, and human health/eco risk assessment.

While many factors affect a firm's adoption of sustainability practices, the drivers tend to be the formal cross-functional responsibility found within these firms, teams, corporate socially responsible culture, the use of environmental and social performance measures, and the presence of a sustainability functional unit. Motivations for implementing DfS activities are impacted by corporate culture. In some situations, the CEO dictates the CSR culture; while in others, environmental champions within functional areas will lead the way.

More innovative firms tended to have environmental specialists and engineers, even climate scientists involved in all of the design processes and they value the inclusion of sustainability performance measures in individual and corporate performance assessment.

Early Adopters are much like innovators, having bought into new environmental concepts early in the concept's life cycle, but unlike innovators, their corporate culture does not emphasize sustainability. Rather early adopters are firms who find it easy to conceptualize, or understand the first mover benefits of sustainability initiatives, and relate these potential benefits to their objectives. These firms tend to look at initiatives from an anticipatory performance measurement and cost savings perspective. Early adopters do not rely on well-established references in making sustainability initiative decisions; they instead prefer to rely on intuition, vision, and developing their own business case for sustainability. Early Adopters become the key to opening up new sustainability initiatives in technology or the adoption of new standards. Adoption of DfS or environmental standards such as EMAS, and ISO 14000 are directly aimed at financial enhancement and competitive advantage. The driving forces for improvements are to seek new technology for waste reduction, pollution prevention, more effective public communication programs, some green labeling of products, auditing and reporting, and frequent management reviews and policy improvements. Early Adopters find the factors affecting value (i.e., flexibility, lead time, cost), the market, and performance measurement to be important to the integration of sustainability issues into new product design. While the design process itself may be formal, there are components of the process that formally and informally integrate sustainability issues. Informal integration is typically the work of a sustainability champion, and formal processes involved check sheets, and cross-functional information systems, and a sign-off at each stage or gate of the product development process.

The *Early Majority* share the innovator's and early adopter's ability to relate to new sustainability initiatives, but are driven by practicality. Our prior research has shown these firms are risk averse, and thereby content to wait and see how others are progressing before they adopt or invest in an initiative. Early Majority firms need a compelling, verifiable reason to change. Sustainability issues are seen as more of an opportunity than an integrated part of business processes. The driving force for sustainability improvements is the threat of current and changing future industry norms, the appearance of potential risk, and regulation. The Early Majority look at sustainability initiatives such as DfS opportunistically and informally. The Early Majority and Late Majority focus more on the elements of value, with budgets sometimes constraining their efforts.

The *Late Majority* consider the costs of new sustainability projects too high to handle. As a result, they wait until there is an established standard before starting a new initiative and showing support. Thus, the importance of established standards discussed in Chapter 4. Late majority firms see the driving force for environmental improvements as favorable public perception of company operations, avoidance of legal liabilities, and protection of the firm's reputation. Sustainability initiatives are looked at only periodically and informally. The Late Majority tend to consider more carefully the trade-offs concerning the allocation of the budget and resources to environmental projects.

The final classification of the firms is the *Laggard.* These firms are last to adopt sustainability, and simply do not want anything to do with new social or environmental initiatives for a variety of reasons. The only time they will buy into initiatives such as DfS is when it is a critical part of their product or when an external group (e.g., customers or regulators) forces it on them. The drivers for sustainability improvements are current regulations and industry norms. Laggards are reactive, focusing primarily on governmental regulations (specifically Occupational Safety and Health Act (OSHA), Resource Conservation and Recovery Act (RCRA), Waste Electronic and Electrical Equipment (WEEE), and Regulation Evaluation, Authorization and Restriction of Chemicals (REACH) regulatory requirements) to drive sustainability policy. For Laggards, sustainability, if it is considered, is the job of the Environmental Health and Safety function and lawyers. Typically, an environmental problem (spill, accident, or injury) is what will prompt action from a Laggard, rather than seeking opportunities for CSR and resource efficiency.

Crossing the Chasm

Firms can, and have, crossed the chasm to improve their sustainable business practices. The existence of the chasm does not, in itself, stop the evolution of firms into better sustainability business practices. Instead, the chasm represents the greater amount of effort needed by a firm to have a proactive stance on sustainable business practices. Innovators and early adopters have formally integrated sustainability issues into the new product design process within firms such as 3M, Bayer Material Sciences, Dow, DuPont, L'Oreal, Herman Miller, Timberland, and Unilever to name a few. Examples can be found within formal processes that integrate environmental concerns within each step of the stage-gate design process. LCA software, databases, and information systems are in place to aid in decision making. Being the first to adopt, the Innovators and early adopters expect to get a jump on the competition via a specialized asset. This jump on the competition can take on several forms, that is, unique resources, reputation, and brand image, legal restrictions to entry and access to new markets, perceived risk reduction by investors, lower product costs, waste reduction, energy reduction, more complete customer service, or other advantages that include employee attrition, learning, and productivity.

By contrast, the Early Majority want productivity improvements for existing operations. DfS will be seen as a way to minimize the discontinuity with the old ways of doing business. By the time these firms adopt DfS, they expect it to work properly and to integrate with their existing systems and standards. The Early Majority and other firms to the right of the chasm take a more opportunistic, or periodic, and informal approach to sustainability. These firms may not have formal systems that help with environmental issues during product development. Instead, these firms may rely on individual champions to address environmental problems when they arise. The Laggards do not even consider sustainability issues.

It has been suggested by Lubin and Esty that sustainability is a strategic imperative for firms.[9] Within this context, the authors suggest leadership needs to have a vision of sustainability and understanding of the value creation process to start. Next, management needs to establish and integrate execution capabilities of which, we know design is a critical element. Whether your firm is involved in assessment, strategy development, or integration, the use of design for sustainability will shape your thinking, manufacturing, and delivery of goods and services in new and profound ways. Crossing the chasm with a focus on value creation and performance metrics may be what enables your firm to take advantage of the sustainability megatrend.

Leveraging Metrics

As shown in Chapter 3, if you do not measure sustainable business practices, you cannot manage sustainable business practices and no one can be held accountable. The idea that metrics and tools are in themselves a solution is a false assumption. Instead, the presence of metrics and tools is an observable *attribute* that helps to verify the presence of sustainability practices and helps a firm to monitor and control its sustainability or DfS practices. The presence or lack of sustainability metrics can be seen in the chasm between the Early Adopters and the Early Majority. The state of performance metrics is a good indicator of the status of sustainability within firms. Innovators have extensive metrics present within their formal system for product development. The metrics can be firm-wide metrics for waste reduction and economic value added, or they can be individually based measures of design speed, cost, and environmental quality. While Early Adopters also have metrics, these firms tend to focus more on the wastes generated from the manufacturing process as a benchmark. Those firms to the right of the chasm lack sustainability measures, and instead rely heavily on environmental regulatory limits of waste generation. These firms tend to think that if they meet the minimum regulatory requirements, everything is fine, yet they miss out on the environmental and economic benefits obtained by leading firms.

A significant difference exists on either side of the chasm when considering the tools available to manage sustainability issues. Innovators and early adopters actively use Environment Management Systems (EMS), LCA, and DfS tools. The separation between the Innovators and early adopters is found in the amount of familiarity and availability of these tools across functions. Those firms right of the chasm lack decision-making tools for sustainability; they may have some sort of EMS available to aid decision making, but do not use these systems or reward for this type of job performance.

The focus on options such as EMS, DfS, LCA, and GHG emission metrics, pollution prevention, reduction, reuse, outsourcing, energy conservation, recycling, and water conservation can be found throughout many firms, especially Innovators and early adopters. Interestingly, we see a greater need for justification of sustainability projects and Return on Investment (ROI) coming into play on the right side of the chasm for the Early Majority. Additionally, Late Majority firms may try to spread environmental risks to supply chain members. This can be done by outsourcing hazardous processes, or by having someone else process and dispose of the waste generated on site. As would be expected by reactive firms such as the Laggards, sustainability options and opportunities are not even considered.

While much of our focus is on the chasm between the Early Adopters and Early Majority, the effort needed for firms to move from no action (Laggards) to some action (Late Majority) will constitute a paradigm shift for many. Crossing what could be construed as a second chasm may lead to the greatest aggregate improvement in the integration of sustainability initiatives and should be a catalyst for all firms to get started. While these practices may not be implemented evenly by all industries, those who choose to explore these environmental practices and DfS will find many opportunities to learn, differentiate, and for innovators and early adopters, gain competitive advantage.

Given the inherent differences in how firms approach integrating sustainability into the product design process, there are a number of frameworks and tools that are available to help you cross the chasm in understanding and operationalizing DfS.

Available Frameworks and Tools to Help Cross the Chasm

Albert Einstein once said "the world that we have created today as a result of our thinking thus far has problems that cannot be solved by thinking the way we thought when we created them." The new way of thinking about the opportunities that comes from environmental and social issues starts with DfS and design thinking and extents throughout the supply chain, and becomes part of an integrated approach to the innovation process. To help in this process, we draw from several frameworks and tools to help the product development process. Some of the leading approaches that allow managers to see the world through a more sustainable lens include C2C design, industrial ecology, the natural step, natural capital, biomimicry, and LCA.

Eco-Effectiveness and Cradle to Cradle

Eco-effectiveness presents an alternative design and production concept to the strategies of zero emission and eco-efficiency.[10] Where eco-efficiency and zero emission seek to reduce the unintended negative consequences of processes of production and consumption, eco-effectiveness is a positive agenda for the conception and production of goods and services that incorporate economic, environmental, AND social benefit, enabling triple top-line growth.

Eco-effectiveness moves beyond zero emission approaches by focusing on the development of products and industrial systems that maintain or enhance the quality and productivity of materials through subsequent life cycles. The concept of eco-effectiveness also addresses the major shortcomings of eco-efficiency approaches: their inability to address the necessity for fundamental redesign of material flows, their inherent antagonism towards long-term economic growth and innovation, and their insufficiency in addressing toxicity issues.

Cradle-to-cradle,[11] also called C2C, or sometimes interchangeable with "regenerative," is a biomimetic approach to the design of systems. Briefly discussed in Chapters 3 and 4, C2C models human industry on nature's processes in which materials are viewed as nutrients circulating in healthy, safe metabolisms. It suggests that industry must protect and enrich ecosystems and nature's biological metabolism while also maintaining safe, productive technical metabolism for the high-quality use and circulation of organic and synthetic materials. This design concept is a holistic economic, industrial, and social framework that seeks to create systems that are not just efficient but not detrimental to the people or the environment, and waste free. The model in its broadest sense is not limited to industrial design and manufacturing; it can be applied to many different aspects of human civilization such as urban environments, buildings, economics, and social systems.

A central component of the eco-effectiveness concept, C2C design provides a practical design framework for creating products and industrial systems in a positive relationship with ecological health and abundance, and long-term economic growth. Against this background, the transition to eco-effective industrial systems is a five-step process beginning with an elimination of undesirable substances. The steps involve:

1. Make sure a product is free of toxic substances.
2. Substitute personally preferred materials that are less hazardous.
3. Assessment of materials and classification as to their ability for biological metabolism—a passive positive list.
4. Optimization of the passive positive list identifying materials as either technical or biological nutrients—creating an active positive list of materials.
5. Reinvention of the relationship of the product and the customer—the product of service concept fits well with this.

Eco-effectiveness ultimately calls for a reinvention of products by reconsidering how they may optimally fulfill the need or needs for which they are actually intended while simultaneously being supportive of ecological AND social systems. This process necessitates the creation of a system of materials management to coordinate material flows amongst processes and whole organizations in the product system. The concept of industrial ecology illustrates how such a system might take shape.

Industrial Ecology

Industrial ecology is an interdisciplinary field involving the relationships between industrial systems and their natural environment. Industrial systems may be conceived on a micro level as firms or industries or on a macro level as industrial societies. The industrial metabolism, that is, the flows of energy and materials through socio-economic structures, is seen as the major driver of environmental burdens and threats to sustainability. Technology in its function of transforming energy and materials into goods and services, and inevitably also into wastes and emissions, is seen as a key to more sustainable solutions.

The term, industrial ecology, was popularized by Robert Frosch and Nicholas Gallopoulos.[12] Following the development of the framework, the field developed during the 1990s and has spawned academic programs, scholarly journals, and an international society. Industrial ecology draws on principles from thermodynamics, systems theory, and ecology. LCA, material flow accounting (MFA), and environmental input-output analysis are primary tools used in the field. Building on the notion of symbiosis in nature, highly interconnected industrial networks using wastes as process inputs (industrial symbioses) should more closely mimic the parsimony of closed-loop natural systems.

A famous example of industrial ecology in practice is an industrial district in the town of Kalundborg, Denmark. This small municipality has a well-developed network of dense firm interactions. The primary partners in Kalundborg, including an oil refinery, a power station, a gypsum board facility, and a pharmaceutical company, share ground water, surface water, wastewater, steam, and fuel, and they also exchange a variety of by products that become feedstocks in other processes. Successful outcomes of this industrial system includes 5 M liters of bioethanol produced annually, 19,500 tons of CO_2 are saved from using excess waste from the adjacent organizations, and 13,000 tons of lignin pellets have replaced coal at a power plant producing electricity and district heat for 5,000 area dwellings in Kalundborg city.[13]

Within this system, there are three primary opportunities for resource exchange: (a) By product reuse—the exchange of firm-specific materials between two or more parties for use as substitutes for commercial products or raw materials. The materials exchange component has also been referred to as a by product exchange, by product synergy, or waste exchange, and may also be referred to as an industrial recycling network. (b) Utility/infrastructure sharing—the pooled use and management of commonly used resources such as energy, water, and wastewater. (c) Joint provision of services—meeting common needs across firms for ancillary activities such as fire suppression, transportation, and food provision. High levels of environmental and economic efficiency have been achieved, leading to many other less tangible benefits involving personnel, equipment, and information sharing.

While in the early phase of this field, the focus was on technologies and firms and their interconnectedness, industrial ecology increasingly broadened its systemic perspective toward including production and consumption, trade and transportation, infrastructure, and lifestyles. Using industrial ecology to create a vision, the industrial transformation of entire economies, cities, industries, and supply chains can come into view.

The Natural Step

The Natural Step (TNS: www.naturalstep.org) is an organization founded in Sweden in the late 1980s by the scientist Karl-Henrik Robèrt. Following publication of the Brundtland Report in 1987, Robèrt developed The Natural Step framework,[14] proposing four system conditions for the sustainability of human activities on earth. Robèrt's four system conditions are derived from the laws of thermodynamics, promote systems thinking, and set the foundation for how we can approach decision making.

The first and second laws of thermodynamics set limiting conditions for life on earth: The first law says that energy is conserved; nothing disappears, its form simply changes. The implications of the second law are that matter and energy tend to disperse over time. This is referred to as "entropy." Merging the two laws and applying them to life on earth, the following becomes apparent:

1. All the matter that will ever exist on earth is here now (1st law).
2. Disorder increases in all closed systems and the Earth is a closed system with respect to matter (2nd law). However, it is an open system with respect to energy since it receives energy from the sun.
3. Sunlight is responsible for almost all increases in net material quality on the planet through photosynthesis and solar heating effects. Chloroplasts in plant cells take energy from sunlight for plant growth. Plants, in turn, provide energy for other forms of life, such as animals. Evaporation of water from the oceans by solar heating

produces most of the Earth's fresh water. This flow of energy from the sun creates structure and order from the disorder.

Taking into account the laws of thermodynamics, in 1989, he drafted a paper describing the system conditions for sustainability. He sent this paper to 50 scientists, asking that they tell him what was wrong with his thinking. On version 22, Robèrt had consensus on what was to become The Natural Step's system conditions of sustainability.

The Natural Step Framework's definition of sustainability includes four system conditions that lead to a sustainable society. In this sustainable society, nature should *not* be subject to systematically increasing:

1. Concentrations of substances extracted from the Earth's crust
2. Concentrations of substances produced as a byproduct of society
3. Degradation by physical means
4. And in that society, people are not subject to conditions that systematically undermine their capacity to meet their needs

Positioned instead as the four principles of sustainability, to become a sustainable society, economy, industry, supply chain, business, or individuals, we must:

1. Eliminate our contribution to the progressive buildup of substances extracted from the earth's crust (e.g., heavy metals and fossil fuels);
2. Eliminate our contribution to the progressive buildup of chemicals and compounds produced by society (e.g., dioxins, Polychlorinated Biphenyl's (PCBs), dichlorodiphenyltrichloroethane (DDT), and other toxic substances);
3. Eliminate our contribution to the progressive physical degradation and destruction of natural processes (e.g., overharvesting forests, paving over critical wildlife habitat, and contributions to climate change); and
4. Eliminate our contribution to conditions that undermine people's capacity to meet their basic human needs (e.g., unsafe working conditions, a non livable wage).

In order to illustrate the issue of sustainability, The Natural Step uses the image of a funnel to demonstrate how decreasing resource availability and increasing consumer demand on those resources will eventually intersect, leading to a breakdown of the system (Figure 5.3). If, however, a company moves toward designing and operationalizing regenerative products, processes and systems, resources and demand can continue forward on a sustainable path.

How can any firm or project team apply The Natural Step framework? A simplified approach, much like Deming's Plan, Do Check, Act, instead positions Awareness, Baseline, Create a Vision, and Down to Action form the acronym ABCD, which describes the four steps of the framework to demonstrate its simplicity and its power.

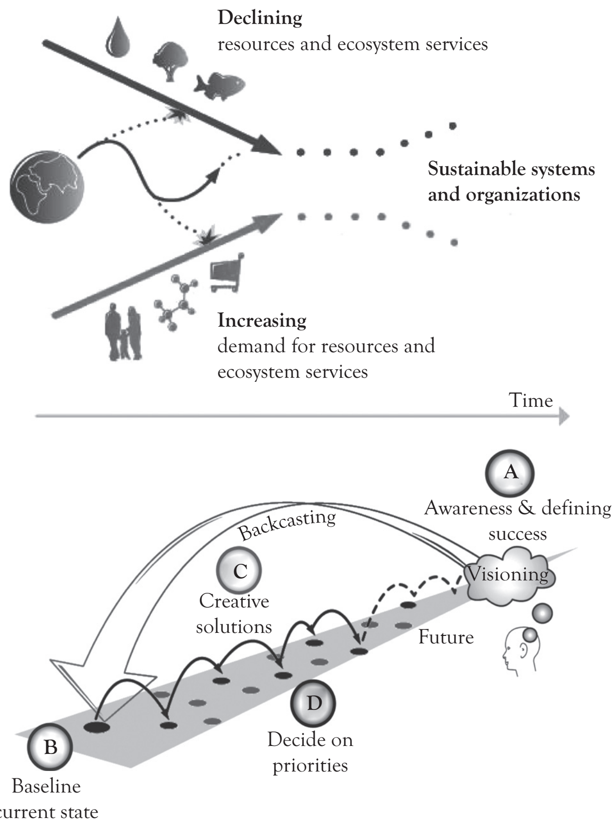


Figure 5.3. The natural step funnel and ABCD application.[15]

Source: Used with permission from The Natural Step

- *Awareness*: Work to create awareness of the idea of sustainability among stakeholders. Begin internally among managers, cross-functional teams and within function champions, include line workers, purchasing, and drivers of trucks. When ready, (meaning when you can demonstrate capabilities and alignment with your value proposition) create awareness externally by releasing information first to your key customer(s) and suppliers and then release this information publicly.
- *Baseline*: Take a close look at all aspects of operations, from stage-gate product design process, to management decision making and key performance indicators. Audit/benchmark current operations to understand the "as is" state and help determine the "to be" state and performance metrics. Include metrics such as GHG emissions, other forms of waste and social performance, transportation system design, supply chain practices, and employee and driver awareness.
- *Create a Vision*: Take what the baseline produced to see where you want to be in the future. Find opportunities for innovation. Set high goals. Define how you will measure success. From these goals, *backcast* to current operations and decision-making utilizing systems thinking to see how decisions today will or will not move you closer to the future vision.
- *Down to Action*: Prioritize goals. Assess projects and initiatives by asking if they take your firm toward or away from its vision. Make the business case for return on investment; is this a good SVA? Create a contingency plan to anticipate risk management factors such as regulatory and cost-structure changes.

By following this framework, whole communities such as Whistler British Columbia, Madison Wisconsin, and Santa Monica California have strategically integrated sustainability into their planning. Multinational corporations such as Nike and IKEA (to name a few) have applied. The Natural Step while integrating supply chains, and applied systems thinking to improve business model alignment of critical customers, capabilities, and value proposition. The result, a collective vision of the future, the use of tools including LCA, metrics and even integrated closed-loop systems to turn the vision into a reality.

Integrating Sustainability and Design: Life Cycle Assessment

The overlay of sustainability within supply chain analysis applies the emerging measurement tools and quantitative models that characterize various relationships and economic trade-offs in the supply chain. Supply chain analysis has made significant strides in both theoretical and practical applications of waste reduction. The application of a sustainability lens to analysis results in an unprecedented mixture of predictive models, and the ability to quantify environmental costs of operations, products, and whole supply chains.

LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by:

- Compiling an inventory of relevant energy and material inputs and environmental releases
- Evaluating the potential environmental impacts associated with identified inputs and releases
- Interpreting the results to help you make a more informed decision

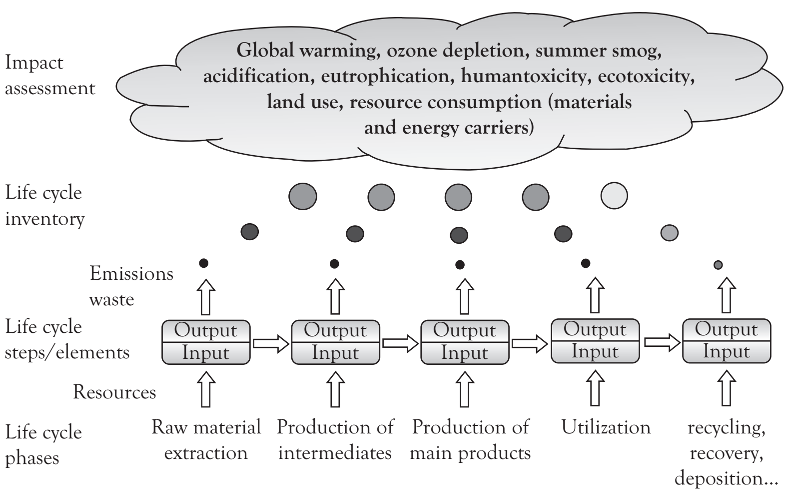


Figure 5.4. Overview of life cycle assessment.[16]

Source: Used with permission from GaBi

LCA is not a new tool, and has evolved over the last forty years. In the 1970s, companies in both the United States and Europe performed comparative life cycle inventory analyses. Inventory analysis is an objective, data-based process of quantifying energy and raw material requirements, air emissions, waterborne effluents, solid waste, and other environmental releases incurred throughout the life cycle of a product, process, or activity. Much of the data was derived from publicly available sources such as government documents or technical papers, as specific industrial data were not available. The process of quantifying the resource use and environmental releases of products became known as a Resource and Environmental Profile Analysis (REPA), as practiced in the United States. In Europe, it was called an Ecobalance. The 1970s also saw the development of an Economic Input Output Life Cycle Assessment (EIO-LCA) method theorized and developed by economist Wassily Leontief. The primary focus of this early period was the development of a protocol or standard research methodology for conducting these studies.

Through the early 1980s, life cycle inventory analysis continued and the methodology improved through studies focused on energy requirements. As interest in all areas affecting resources and the environment grew, researchers further refined and expanded the methodology beyond the life cycle inventory, to impact. Impact assessment refers to the phase of an LCA dealing with the evaluation of environmental impacts (e.g., global warming and toxicity) of products and services over their whole life cycle.

During the 1990s, false claims of environmental product attributes along with pressure from environmental organizations to standardize LCA methodology, led to the development of the LCA standards in the ISO 14000 series. Researchers at the Green Design Institute of Carnegie Mellon University operationalized Leontief's EIO-LCA method in the mid-1990s, with the help of sufficient computing power. This model is still available is available online taking the EIO-LCA method and transforming it into a tool available to quickly evaluate a commodity or service, as well as its supply chain.

After the turn of the century, the UNEP joined forces with the Society of Environmental Toxicology and Chemistry (SETAC) to launch the Life

Cycle Initiative, an international partnership. The programs of the Initiative aim at putting life cycle thinking into practice and at improving the supporting tools through better data and indicators. The Life Cycle Inventory (LCI) program improves global access to transparent, high-quality life cycle data by hosting and facilitating expert groups whose work results in web-based information systems. The Life Cycle Impact Assessment (LCIA) program increases the quality and global reach of life cycle indicators by promoting the exchange of views among experts whose work results in a set of widely accepted recommendations.[17] There are currently several proprietary software solutions to help make LCA a reality. The two most used in the U.S. and EU are Simapro and GaBi, respectively.

Drill Down into Available Materials and Process Information

LCA quantifies the environmental impacts at each step of a product's life cycle. As a tool, LCA can be used to sustainably design products and even supply chains so that they have the least negative environmental impact.[18] Life Cycle Management (LCM) is the application of life cycle thinking to modern business practice, with the aim to manage the total life cycle of an organization's product and services toward more sustainable consumption and production.[19] It is an integrated framework of concepts and techniques to address environmental, economic, technological, AND social aspects of products, services, and organizations.

LCM is supported by environmental management systems and the ISO 14001 standards for these systems and research showing positive impacts on design, waste reduction, and recycling.[20] Additional resources are available online through the EPA, the National Services Center for Environmental Publications, and the Risk Management Sustainable Technologies web sites. The benefits from these systems include proactive environmental management, resource and cost efficiency, enhanced reputation, and improved communication.[21] LCA-specific standards include ISO 14040 to 14044 as they describe the primary principles and framework for LCA including four primary steps:

1. Definition of the goal and scope of the assessment including system boundaries
2. The life cycle inventory analysis phase
3. The life cycle impact assessment phase
4. The life cycle interpretation phase, reporting and critical review of the assessment, limitations, and relationships between the four primary assessment phases

Clarification of some terminology is needed to better understand LCA boundaries. Below are the main options to define the system boundaries used (shown in Figure 5.5):

Cradle to Grave: includes the material and energy production supply chain and all processes from the raw material extraction through the production, transportation, and use phases up to the product's end of life treatment.

Cradle to Gate: includes all processes from raw material extraction through the production phase (gate of the factory); used to determine the environmental impact of the production of a product.

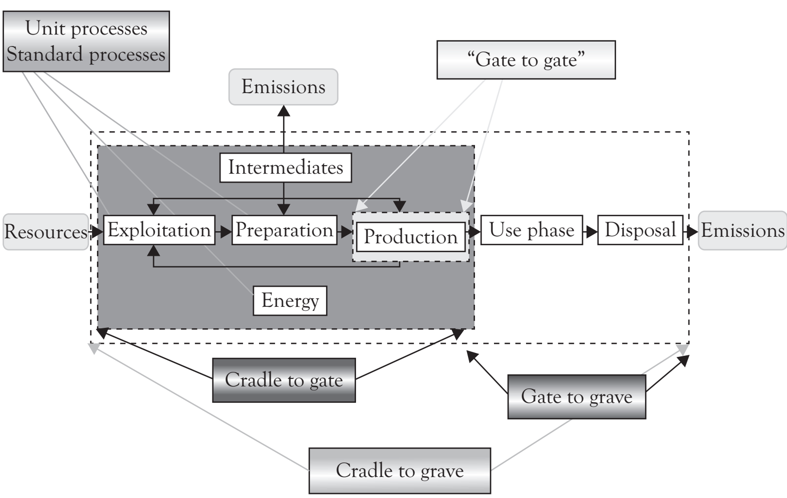


Figure 5.5. System boundaries

Source: Used with permission from Gabi.

Gate to Grave: includes the processes from the use and end-of-life phases (everything post production); used to determine the environmental impacts of a product once it leaves the factory.

Gate to Gate: includes the processes from the production phase only; used to determine the environmental impacts of a single production step or process.

Cradle to Cradle: includes the material and energy production supply chain and all processes from the raw material extraction through the production, transportation, and use phases before the product goes back into transportation closing the supply chain loop becoming a material used again in production, transportation, and use.

Clearly understanding the goal, scope, and system bounds allows LCA to be used as a tool to measure and track a product's resource use and impacts from cradle to grave, from raw material extraction to end-of-life processes. This tool is essential for managing sustainability risks, reducing waste and discovering opportunities to create environmentally and socially driven value. An established approach to a macro level of analysis involves systems thinking. This holistic approach to analysis focuses on the way that a system's constituent parts interrelate and how systems work over time and within the context of larger systems.[22] Conducting an LCA is one way to understand interconnected supply chain systems of products and services. The outcomes of an LCA lend themselves to supporting the ISO 14025 standard for environmental product labels and declarations.

A cradle-to-grave LCA allows a decision maker to study an entire product system and supply chain hence avoiding the sub optimization that could result if only a single process were the focus of the study. Stonyfield Farms in New Hampshire conducted an LCA on their yogurt product-delivery system to compare options for containers. Knowing the size of the container and the distance to retailer were important factors impacting the environment, they found that if they sold all of their yogurt in 32-ounce (0.95 liters) containers, they could save the equivalent of 11,250 barrels of oil per year. Transportation to the retailer represented about a third of their products' energy impact.[23]

At 3M, the protocol for new product development includes assessment of environmental, health, and safety issues at suppliers, within 3M, and with the customer. This approach to understanding full-system impacts of its products gives 3M a foundation for building strategies leveraging an eco-advantage. Similar initiatives are taking place at companies such as Alcoa, Bayer Material Science, Dow, DuPont, and PPG where teams of LCA experts are now plugged into cross-functional teams in design and supply chain management. Resource efficiency and LCA become tools for pollution reduction and waste minimization allowing managers to better understand where they can have the most impact on a design, process, and supply chain.

Design Better Products, Packaging, and Supply Chains

Good managers know it's important to scan their external environment. They now look for the eco and social consequences of their products all along the value chain, upstream and downstream. Supply chain analysis tools and methods to integrate sustainability are most effective when they rest on a foundation of good data, careful planning, and an environment management system. Companies are now managing worldwide databases of sustainability performance metrics. Establishing key metrics such as GHG emissions that track results on energy use, water and air pollution, waste generation, and compliance help decision makers benchmark performance, optimize supply chains, set goals, and monitor progress.

Closing the Loop

We should stop throwing away billions of dollars of valuable recyclable packaging materials, according to a report highlighting how the United States' lagging packaging recycling rates result in serious market inefficiencies and unnecessary strain on the economy and environment.[24] Packaging comprises over 40% of the U.S. solid waste stream, greater than any other category, and most of the materials are recyclable. Findings in the report include an estimate that the value of wasted recyclable consumer packaging materials exceeded $11 B and how Extended Producer Responsibility (EPR) can lead to profits in processing used materials, reductions in carbon emissions and energy used to produce packaging, and thousands of jobs in within closed-loop supply chains for collection and processing. Further information from McKinsey finds manufacturers can create value, cut costs, and reduce exposure to volatile commodity prices by improving their resource productivity—using fewer resources for each unit of output.[25] Leaders are looking for opportunities beyond their own operations. Collaboration with suppliers and customers can keep used products, components, and materials in circulation while creating upwards $380 B of potential annual net material cost savings within the EU. New business models that rethink the concept of ownership can shift value within closed-loop systems.

"Americans throw away more materials than any other country," said Conrad MacKerron, author of the report. "This used to be a sign of economic progress, but in an age of declining natural resources, such waste is now an indicator of inefficient use of valuable raw materials and market failure. It's simply not good business to throw away billions of dollars of reusable resources."

Information within the report outlines why companies should design closed-loop systems and take responsibility for post-consumer packaging as part of their ongoing sustainability policies. Packaging represents an overlooked system and industrial ecology opportunities because raw materials, such as the petroleum, minerals, and fiber used to make much consumer packaging, are projected to become increasingly scarce. The authors

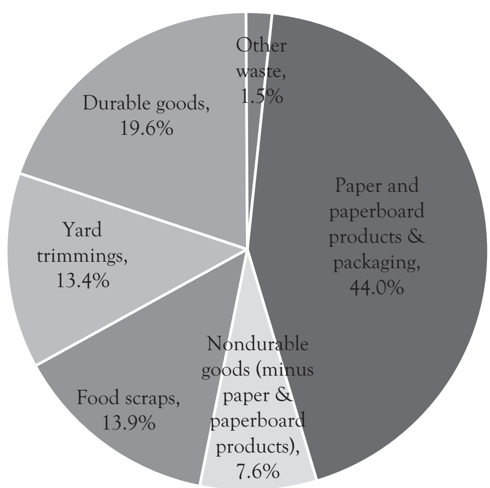


Figure 5.6. Percentage of solid waste steam.

of the report also find that efficiently designed and administered EPR policies would resolve many of the concerns identified with packaging recycling by:

- Increasing recovery rates for all post-consumer packaging
- Incentivizing producers to reduce materials use and improve recyclability
- Creating profitable secondary materials markets
- Providing stable revenue sources through producer fees to improve curbside recycling systems and build new recycling infrastructure
- Reducing energy consumption and GHGs
- Meeting pent-up industry demand for recyclable materials

A group of major consumer goods and grocery companies, including Colgate-Palmolive, General Mills, Kraft Foods, Safeway, Supervalu, Target, Kroger, Procter & Gamble, Unilever, Walmart, Whole Foods, Coca-Cola, and Nestlé Waters, are already working on solutions to help adopt EPR policies. By supporting the design of EPR policies that drive more aggressive and effective collection efforts, companies can then make commitments to use far higher levels of recycled content in product packaging, which, in turn, supports closed-loop systems ensuring a stable supply of post-consumer materials to use as new feedstock.

Why this is relevant to supply chain design and management? Does it only mean there is now more work for everyone? To answer the first question, supply chain professionals should have a seat at the design table and new sustainability projects. Supply chain insight should be involved early and often in the stage-gate NPD process and work with the growing ranks of sustainability professionals. With the increased focus on energy reduction initiatives within buildings, energy conservation thinking should be extended to transportation systems, moving more goods with fewer resources and minimizing fuel consumption.

To answer the second question, no, everyone does not have more work, but instead this is an opportunity to quickly move up the learning curve on sustainability and realize we all can reimagine products, processes, and systems. This is not more work, but a different way of approaching the work you already perform. Each one of us can find and eliminate waste, improve the business model, and rethink the way we design with key customers in mind. There are already available, proven approaches to help organize and focus on the integration of sustainability within existing processes. Systems thinking, stage-gate NPD processes, Industrial Ecology, The Natural Step, and C2C design all enable us to see the world as dynamic and inter related rather than static and limited to functional siloes.

Companies overlooking the opportunity to manage sustainability and closed-loop systems face risk from investors. In 2002, the CDP Project surveyed and requested carbon information from the Financial Times 500 largest companies with only a 10% response rate. By 2005, the response rate increased to 60% of the same companies surveyed.[26] Now, 80% of the Financial Times submit annual carbon footprint reports. With the exponential growth in sustainability reporting and the integration of financial and sustainability reports, there will be an increase in the development of material database that includes information on suppliers and where all components and parts come from for a given product. Increased supply chain transparency has already led to open source, online LCA collaboration platforms such as Sourcemap.com where anyone can see exactly where a product comes from, what kind of environmental impacts materials have from extraction, to transportation to the retail location, and delivery to your home.

The benefits are already be seen by some innovative firms such as DuPont. At the turn of the century, forward-thinking leaders pledged to cut carbon emissions 65% below their 1990 levels and to accomplish this by 2010. The company reduced its emissions 67% while the value of DuPont stock increased 340%. By 2007, they had reduced company emission 80% below 1990 levels. These same efforts saved the company $3 B between 2005 and 2010.

Role of Transportation Providers

Transportation service providers should see sustainability as a way to efficiency and productivity and manage transportation and logistics functions for their customers while also being considered early in the product design process. Sustainability allows the transportation and logistics function of any firm to create value by working with customers at a strategic level and by backing decisions with very detailed data from the product design process and application of LCA tools. While the business case for new initiatives often come as band aids and incremental improvement, combining sustainability and design thinking provides opportunities to leapfrog chasms and possibly cross the largest chasm between the Early Majority and Early Adopters.

When it comes to DfS product applications, the possibilities are limitless, but we realize that your time is not. The best approach is to assemble teams to get up to speed on sustainability initiatives within your industry. Then, perform gap analysis and review internal needs. Create a vision and set high sustainability goals, review the possible solution sets available through DfS, and backcast into current decision-making. The use of teams and looking at the world through a design thinking lens will allow many to more quickly integrate sustainability into practice and performance metrics, and make timely proposals to improve efficiency and productivity.

Solutions can include a design focus on a spectrum of opportunities that include but are not limited to: shipment scheduling (inter plant, inbound, and outbound), mode and mode-mix selection, optimization, carrier network development and management, transportation planning, load tendering, tracking and tracing, claims processing, freight bill payment, returns management, benchmarking, and reporting.

However, new initiatives demand products, processes, and solutions that are more practical, that is, more user friendly, easily implemented, and less disruptive to existing systems. Sustainability is too often positioned in terms of new metrics. Thus, management needs to understand trade-offs, managing to what's critical and not doing everything at once. One way to approach this is to look for solutions that are designed to be:

- **Proactive**, understanding your business model and how you compete relative to others in your industry.
- **Effective**, allowing you to get more total product movement for less total cost.
- **Evenhanded**, not choosing one solution over another solely due to sustainability, but instead focus on the best solution for your business model.
- **Realistic,** effectively operationalized and understandable in existing financial terms.

Original Equipment Manufacturers (OEMs) and retailers value their relationships with transportation providers and recognize that they can reduce the impact of product movement. Key customers will look for their transportation partners to evaluate and minimize their fuel costs and environmental impacts by:

- Retrofitting existing vehicle fleets with technologies that increase fuel efficiency
- Implementing process and practice changes to reduce fuel consumption
- Training drivers in fuel-efficient driving techniques
- Replacing existing inefficient vehicles with new, high-efficiency vehicles
- Redesigning products and packaging to increasing packing rates with opportunities for closed-loop systems and recycling

EPA's SmartWay program (previously described in Chapter 3) provides resources, educational content, and financing for making more fuel-efficient transportation a reality and is a logical resource for modernizing your own fleet, or understanding what fuel-efficient practices you should expect from transportation providers.

Summary

Our own work with companies integrating sustainability has shown a concern for what some have described as a "myopic focus on costs." While costs are important, Innovators and early adopters have been able to realize cost savings through better design, leveraging transportation, lengthening ROI and payback timelines on new projects, while leveraging the SVA of sustainability opportunities. This is important for several reasons as a firms focus will move from products, to processes and to packaging, you need to answer the question "how do we change processes to eliminate waste, or do we simply go after the outputs?" By understanding if your current efforts are process or output driven, you will be able to recognize opportunities to design proactively for more effective supply chain management.

Applied Learning: Action Items (AIs) and Audit Questions (AQs)—Steps you can take to apply the learning from this chapter

AI: Where is your firm on the sustainability adoption model?

AI: Review The Natural Step conditions and apply this framework to your operations, what issues become apparent?

AI: Can you find opportunities for LCA and industrial ecology within your operations and supply chain??

AQ: Who are the innovators and early adopters of sustainability in the transportation industry?

AQ: To what extent is sustainability integrated into your product design processes, or the processes of your customer?

AQ: To what extent are the following options considered in your organization (product/process redesign, LCA, disassembly, substitution, reduce, recycle, remanufacture, consumer internally, waste segregation, alliances)?

For a more in-depth assessment, and to receive summary information of your AQs relative to others, visit the Sustainable Supply Chain Assessment tool for this book at: www.duq.edu/sustainable-supply-chain-management

Further Reading

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