CHAPTER 1
Introduction

The challenge is to build a new economy and to do it at wartime speed before we miss so many of Nature's deadlines that the economic system begins to unravel. —LESTER BROWN [1]

A Sense of Urgency

Human prosperity and environmental integrity are closely intertwined because the fulfillment of basic human needs—food, clothing, materials, energy—ultimately depends upon the availability of natural resources. Since the dawn of *homo sapiens,* we have recognized this fact, and in most ancient cultures nature was respected and revered. Yet, over the last several hundred years, during a period of dramatic industrialization, innovation, and global expansion, we humans have not only taken the natural environment for granted, but we have literally plundered and abused nature to serve our growing appetites. With no natural enemies, we conquered the planet, only to realize that we may be our own worst enemy.

Thankfully, over the last fifty-odd years, we gradually rediscovered the importance of protecting vital resources, such as soil, air, water, trees, and other organisms. What began as a fringe movement in the 1960s has evolved into a mainstream concern, as economists and politicians have gradually recognized that we are depleting fossil fuel resources and pumping greenhouse gases into the atmosphere at an alarming rate. Yet even today, many people do not understand the magnitude of these problems and tend to trivialize the solutions. Environmental awareness has become chic and is embraced by celebrities and brand marketers, while our major industrial systems continue to operate as before, with superficial changes. The good news is that we are no longer in denial, but the bad news is that we can't seem to break our old habits.

Perhaps we need another wake-up call. Global warming is only one of many disturbing trends identified by the scientific community—

sea level is rising, fresh water is growing scarce, we are running out of arable land, our forests are disappearing, and biodiversity is threatened due to changes in natural habitats. Meanwhile, global population continues to increase; more countries are developing into resource hogs, while over three billion people still live in abject poverty on less than $2.50 per day, many deprived of even basic sanitation and fresh water.

Humans are nothing if not ingenious problem-solvers. Can we cleverly escape, like Indiana Jones, from this predicament in which we find ourselves? We are faced with the most daunting set of problems in our recorded history. Once we squarely confront these problems, we have two paths to choose—hopeless or hopeful:

1. The hopeless path is to resign ourselves—accept that the world will soon run out of resources; that there will be an inevitable collapse of civilization; and that our best alternative is to hunker down, break our dependencies, become self-sufficient, live off the land, and pray that we are not destroyed in a global conflict or natural catastrophe.
2. The hopeful path is to reinvent our way of life—not to retreat but to join forces in an unprecedented sustainability campaign. We are past the point where better housekeeping will solve the problem. We need to completely redesign industrial products, processes, and supply chains to dramatically lower their resource intensity, while assuring that developing nations do not replicate the old designs.

Pursuing the hopeful path will require extraordinary collaboration. While breakthrough innovation can be accomplished by the private sector, governments and private citizens also have an important role to play. First, we need a governance framework for sustainability that provides the right incentives while minimizing the barriers to change. Second, we need to redesign the publicly managed physical infrastructure systems that support economic activity—transportation, energy, water, and waste management. Finally we need to accomplish a massive behavior change in order to shift toward sustainable consumption patterns.

This journey will be an enormous challenge—a moonshot for the twenty-first century. We have already waited too long, and we need to act with a sense of urgency. Achieving sustainability will draw upon the best thinking in every discipline—management and engineering, science and policy. This book does not provide a complete blueprint for the journey to sustainability, but it does provide some important tools for slowing and perhaps even reversing environmental degradation through innovative product and process design.

The Basic Premise

The underlying premise of this book is that environmental sustainability is compatible with economic development. Just as growth is essential to living organisms, growth is also essential to a healthy society, especially in developing nations afflicted by widespread poverty [2]. But to achieve global sustainability, *we need to radically redesign our industrial systems to create more value with fewer resources*. The idea of sustainable growth is a departure from traditional world views, in which environmentalists considered industry to be the enemy and businesses considered environmental protection to be a burden. But it is not pie-in-the-sky idealism. Global manufacturers in virtually every industry category are adopting sustainability goals, and environmental activist groups have begun to collaborate with them. Sustainable development through "eco-efficiency" has become the rallying cry of companies who see competitive advantage in conservation of resources and environmental stewardship. This book is filled with examples of leading companies who have embraced these concepts. Here are a few notable examples:

- Dow Chemical has adopted sustainability as a strategic imperative throughout its global businesses. Over the decade from 1995 to 2005, Dow spent about $1 billion on environmental, health, and safety improvements and realized about $5 billion in value (see Chapter 13).
- General Electric's ecomagination[SM] portfolio of energy efficient and environmentally advantageous products and services exceeded $17 billion in 2008 and has been the company's fastest growing segment, even during the economic downturn.
- Wal-Mart, the retail giant, has adopted aggressive environmental goals for energy and waste reduction, and has urged its suppliers to help meet these goals through product development, packaging, and transportation (see Chapter 19).
- The World Business Council for Sustainable Development, based in Geneva, is a consortium of over 150 global companies that have been working together since 1990 on global sustainability issues such as climate change and clean water.

While large corporations speak enthusiastically about sustainability, some critics have assailed the "win-win" philosophy as misleading, claiming that environmental management costs will continue to outweigh the benefits and that regulatory controls are the only reliable way to reduce industrial wastes. As early as 1970, the eminent economist Milton Friedman declared that corporate social and environmental responsibility was a distraction from the fundamental purpose of a corporation—to create value

for shareholders. In other words, "the business of business should be business." It is certainly true that environmental initiatives do not automatically produce financial benefits; they need to be evaluated in the same light as any other investments. However, it is also true that a full consideration of environmental factors and trade-offs will reveal opportunities to simultaneously enhance customer satisfaction, profitability, and competitiveness. This will be amply demonstrated in later chapters. In the long run, businesses can only remain competitive if they are attuned to the broader needs of society. In the words of management theorists Michael Porter and Mark Kramer [3]:

WE NEED TO RADICALLY REDESIGN INDUSTRIAL SYSTEMS TO CREATE MORE VALUE WITH FEWER RESOURCES.

> The mutual dependence of corporations and society implies that both business decisions and social policies must follow the principle of *shared value*… a company must integrate a social perspective into the core frameworks it already uses to understand competition and guide its business strategy.

The Hidden Mountain

The commitment of major corporations to environmental sustainability is certainly a hopeful sign. Yet, even with widespread adoption of corporate environmental responsibility, worldwide levels of energy and material use continue to rise. Paradoxically, the more efficient companies become in terms of resource utilization, the more rapidly the global economy grows; this is known to economists as the "rebound effect." It is becoming apparent that voluntary, incremental environmental improvements by individual companies will be inadequate to significantly offset the growth of the global economy. The rapid industrialization of China, India, and other emerging economies will likely exacerbate this problem. Ecological footprint analysis suggests that humanity's ecological demands already exceed what nature can supply, and we are now eroding our "natural capital" rather than living off the interest (see Chapter 9). Clearly, we need to dig deeper into the source of the problem.

Few of us in the developed world are aware of the enormous environmental impacts of our everyday lifestyles. As we pursue our habitual patterns—mealtimes, commuting to work, occasional recreation—we have no clue about the hidden flow of resources needed to support these seemingly innocent activities. Each of us is actually living on top of a mountain of resources, including energy and materials, all of which originated from the natural environment. Ecological goods and services are embedded in everything that we consume (see Figure 1.1). It has been estimated that the average American citizen accounts for about 30 metric tons of material per

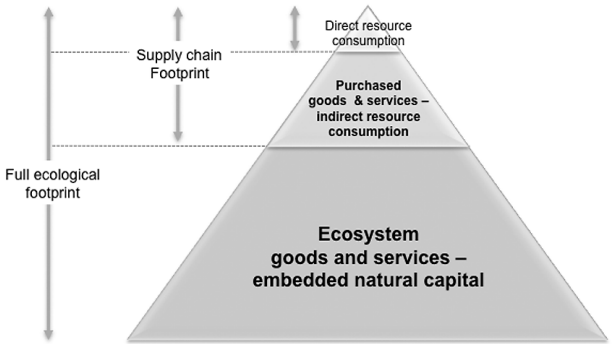

Figure 1.1 The hidden mountain of resource consumption.

year [4]. We never see most of that material because it is released to the environment in the form of trash, wastewater, and airborne emissions—mainly carbon dioxide. Only about 5% finds its way to the customer in the form of consumable products such as food, and durable goods such as furniture. A small fraction is recycled, but the rest is simply thrown away.

For example, assuming that an individual consumes 1 plastic quart bottle per day, her annual consumption generates about 5 kg of solid waste per year (11 lb). Recycling may reduce that total, although it still requires resources to bring the bottles back to the point where they reenter the manufacturing stream. However, if we consider the resources—both energy and materials—required in the full *life cycle* for those plastic bottles, including resource extraction, manufacturing, and transportation, it requires a total of about 250 kg of materials per year, 98% of which end up as solid waste. In addition, the supply chain associated with plastic bottle manufacturing consumes about 20 liters of water per bottle, amounting to about 230 million metric tons of water per year for the U.S. as a whole. This enormous water footprint is mainly due to thermo-electric power generation and crop irrigation [5].

Plastic bottles are not unusual in this respect. The processes involved in manufacturing and supporting most products have significant impacts on the environment, including the generation of waste, the disruption of ecosystems, and the depletion of natural resources. About 20 billion tons of industrial wastes are generated annually in the United States, and over a third of these are hazardous wastes. As a result, U.S. communities are rapidly filling up available landfill space. In the European Union, where unused land is scarce, a number of strict directives have been issued that require manufacturers to recover and recycle discarded products and packaging (see Chapter 3). But still the mountain grows.

The sobering message is that our current patterns of industrial development threaten to exceed the capacity of ecosystems in terms

of resource utilization and waste absorption, and also pose potential threats to global climate, vegetation, and agriculture. Who is responsible for this escalating crisis—complacent consumers or profit-driven producers? Unfortunately, contentious debates are only a distraction from developing solutions. Playing the blame game is not going to help—we need to accept our collective guilt and move on. Making real progress will require disruptive innovation and fundamental redesign of industrial systems.

The Emergence of DFE

The concept of Design for Environment (DFE) originated in the early 1990s, largely through the efforts of a handful of private firms that were attempting to build environmental awareness into their product development efforts.* The strategic importance of DFE and examples of DFE practice were first described in an innovative 1992 report by the U.S. Congress Office of Technology Assessment [6], and in the same year the American Electronics Association produced a ground-breaking primer for the benefit of member companies [7]. Since that time, the level of interest has mushroomed, and DFE has become a common theme in corporate environmental stewardship and pollution prevention programs. Typically, the scope of DFE includes the following objectives:

- Environmental protection—assurance that air, water, soil, and ecological systems are not adversely affected due to the release of pollutants or toxic substances.
- Human health and safety—assurance that people are not exposed to safety hazards or chronic disease agents in their workplace environments or personal lives.
- Sustainability† of natural resources—assurance that human consumption or use of natural resources does not threaten the availability of these resources for future generations.

For purposes of this book, we view DFE as a collection of design practices aimed at creating products and processes that address the above objectives. Hence the following definition:

> **Design for Environment** is the systematic consideration of design performance with respect to environmental, health, safety, and sustainability objectives over the full product and process life cycle.

*DFE is often referred to by other names, including Eco-Design, Life Cycle Design, Design for Eco-efficiency, and Sustainable Design.

†This is "sustainability" in the narrow sense originally intended. The term has evolved into a popular buzzword used to encompass environmental, health and safety, economic, social and ethical issues.

The practice of DFE has spread quickly in today's business environment, as major firms have recognized the importance of environmental and social responsibility to their long-term success. Even the U.S. Environmental Protection Agency has established a DFE program to encourage reduction of pollution at the source (see Chapter 3). The company case studies in Part 3 of this book illustrate how DFE provides competitive advantage by reducing the costs of production and waste management, driving product innovation, speeding time to market, and attracting new customers. The business benefits of DFE are summarized in Figure 1.2, and are further described in Chapter 4.

Example Here is a recent example of DFE applied to sustainable packaging: Sam's Club redesigned its milk jugs with a new cubical shape that is easier to transport. The company estimates that this kind of shipping has cut labor by 50% and water use for cleaning by 60 to 70%. More gallons fit on a truck and in Sam's Club coolers, and no empty crates need to be picked up, reducing trips to each Sam's Club store to two a week from five—a substantial fuel savings. Also, Sam's Club can now store 224 gallons of milk in its coolers in the same space that used to hold 80. The only drawback was that consumers had a hard time getting used to pouring milk from the new jugs. However, the company was able to pass on savings of 10 to 20 cents per gallon to the consumer.

DFE originated in the early 1990s due to the convergence of several driving forces that made global manufacturers more aware of the environmental implications of their product and process designs. For one thing, consumers were becoming increasingly concerned about the environmental "friendliness" of the products that they purchase. The International Organization for Standardization (ISO) was developing the 14000 series of standards for environmental

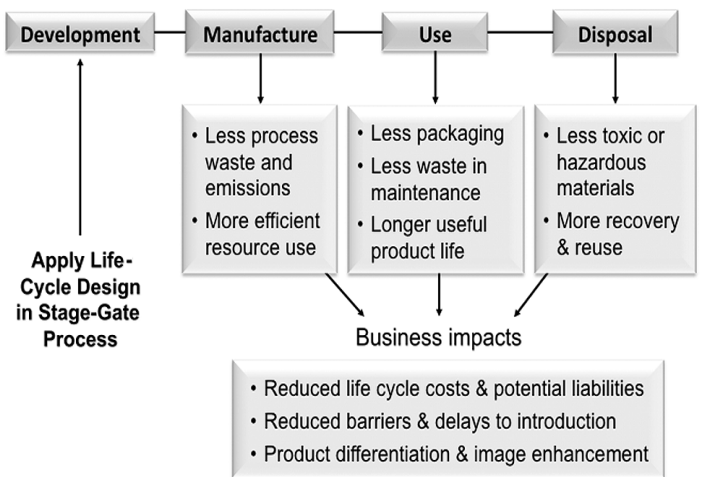

Figure 1.2 Benefits of Design for Environment.

management systems, analogous to the ISO 9000 series for quality management systems. Many government agencies, notably in the European Union, were taking aggressive steps to assure that manufacturers are responsible for recovery of products and materials at the end of their useful lives. At the same time, there was a growing voluntary commitment on the part of major manufacturing firms to assure environmental responsibility for both their internal operations and their suppliers. This led to the flourishing of consortia such as the Global Environmental Management Initiative and the World Business Council for Sustainable Development, as well as government-sponsored programs such as ENERGY STAR. All of these historic changes are described in Chapter 3.

DFE can be seen as a conceptual crossroads between two major thrusts that began in the 1980s and transformed the nature of manufacturing throughout the world. As illustrated in Figure 1.3, these two thrusts are *enterprise integration* and *sustainable development*.

Enterprise integration is the reengineering of business processes and information systems to improve teamwork and coordination across organizational boundaries, thereby increasing the effectiveness of the enterprise as a whole. The total quality management (TQM) movement provided a strong motivation for enterprise integration, and *integrated product development* (IPD) has been widely adopted as a strategy for agile manufacturing, allowing companies to release higher-quality products while reducing time to market. As described in Chapter 5, IPD involves cross-functional design teams who consider the entire spectrum of quality factors, including safety, testability, manufacturability, reliability, and maintainability, throughout the

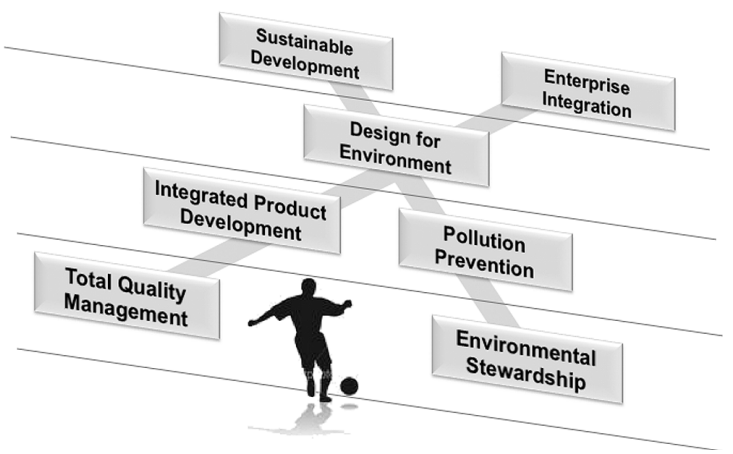

Figure 1.3 DFE is at the crossroads between enterprise integration and sustainable development.

product life cycle. Since environmental performance is an important aspect of total quality, DFE fits naturally into this process—in fact, *life-cycle thinking* is at the core of DFE.

Sustainable development is industrial progress that "meets the needs of the present without compromising the ability of future generations to meet their own needs" [8]. The implied challenge is how to assure continued industrial growth without adverse ecological and social impacts. To address this challenge, the traditional economic concept of exchange value must be extended to include both man-made and natural capital (see Figure 1.4). Instead of accounting purely for the labor and man-made materials that are inputs to production, the broader approach of *ecological economics* takes into account the value of natural resource inputs and the effect of waste outputs [9]. Sustainability has recently emerged as a prominent global issue due to concerns about shrinking fossil fuel reserves and evidence of global warming. As mentioned above, climate change is just one of many sustainability issues that need to be considered in a broader systems view of economic development.

Historically, the issues addressed in DFE were managed by environmental, health and safety (EH&S) groups that tended to be isolated from the mainstream in terms of both the strategic and the operational aspects of a business. However, the role and positioning of EH&S groups have shifted, and sustainability issues that were previously considered esoteric have been incorporated into a comprehensive business strategy. The emergence of DFE has resulted in active collaboration among company groups that rarely had contact in the past—environmental managers and product development managers.

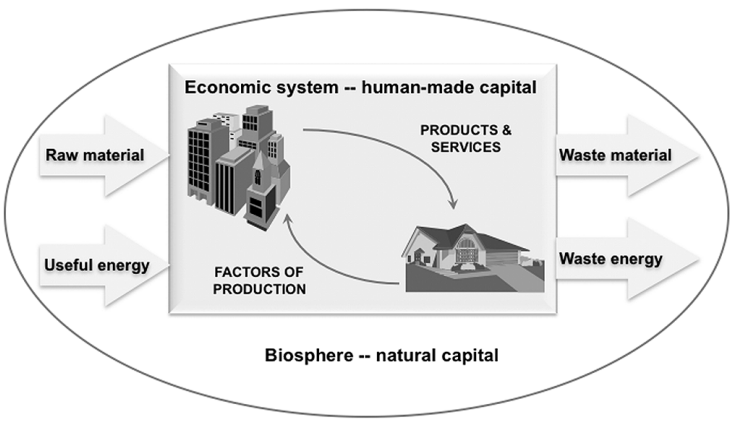

Figure 1.4 Broadening traditional economics to include natural capital (adapted from [9]).

Moreover, companies are increasingly working with suppliers, customers, and external stakeholders to design sustainable solutions. This book describes the exciting opportunities that are made possible by this collaborative, enterprise-wide approach.

DFE Implementation Challenges

A newfound passion for sustainability has led many companies to set aggressive environmental performance goals and issue glossy reports extolling their commitment to environmental and social responsibility. But veteran companies that have walked this path for years realize that putting these concepts into practice in a way that genuinely transforms a business is not as simple as it may appear. It is relatively easy to "pick the low-hanging fruit" by adopting best practices such as low-energy lighting systems and recovery of post-industrial scrap. With a bit more effort, companies can implement ISO 14001-style environmental management systems and measure their continuous improvement in performance. A much greater challenge is to integrate sustainability thinking into a company's business processes to achieve significant, lasting change. In particular, to perform Design for Environment consistently and effectively is challenging for several reasons:

- The necessary environmental expertise is not widely available among product development teams, including marketers and engineers.
- The complex and open-ended nature of environmental phenomena makes it difficult to analyze the effects of design improvement.
- The economic systems in which products are produced, used, and recycled are much more difficult to understand and control than the products themselves.

Despite the many examples of successful DFE efforts described in this book, the current state of DFE practice can be characterized as mainly opportunistic. Well-motivated and well-informed teams may be able to identify product improvements that are environmentally beneficial or that reduce life-cycle costs. However, in order to implement DFE fully as a component of the new product development process, systematic methods and processes must be introduced and integrated into the daily work of development teams. Much of this book is devoted to describing these methods, including stage-gate processes, design guidelines, performance metrics, and analytical tools.

Finally, it is important to position DFE correctly in the broader context of corporate innovation and social responsibility. As described in Chapter 4, those companies that consistently deliver shareholder value combine a relentless drive for technological superiority with

an acute awareness of the expectations of stakeholders. DFE is part of a broader landscape in which companies continuously reexamine emerging challenges and opportunities, identify critical drivers of superior performance, evaluate the competitive position of their products and processes, and pursue purposeful innovation to achieve sustained excellence. Environmental, health and safety performance is one of many considerations that are part of this strategic feedback loop. Other key characteristics of a successful and resilient company include engagement with its key stakeholder groups, transparency of its communications, diversity of its workforce and suppliers, assurance of ethical practices such as avoidance of child labor, and contribution to economic development in the regions in which it operates (see Chapter 20).

Using This Book

This book describes the basic principles of DFE and outlines the steps necessary to make DFE an integral component in the design and development of new products and processes. For those companies who see the wisdom of DFE and wish to embark on this path, this book provides a guide to the design and development of environmentally responsible products and processes. Consider it a roadmap to sustainable product development.

Part 1, *Answering the Call*, describes the emergence of corporate environmental responsibility in the United States and abroad, including the transition from regulatory compliance to corporate responsibility and the broad range of voluntary initiatives sponsored by government, industry, and nonprofit organizations. It focuses specifically on the external forces and business drivers that motivate adoption of sustainability and DFE practices.

Part 2, *Charting the Course*, explains how DFE fits within the broader paradigm of concurrent engineering for integrated product development and life-cycle management. It sets forth the principles and methodology for implementation of DFE, including life-cycle thinking, performance metrics, design rules and guidelines, and supporting analysis tools.

Part 3, *Walking the Talk*, consists of a series of chapters that describe DFE practices in a variety of industries, ranging from basic commodities to consumer products and services. Each chapter contains case studies from several progressive companies in the United States and abroad, describing their approach to DFE and the lessons that they have learned.

Part 4 concludes with an examination of the global challenges involved in the journey to environmental sustainability and discusses how we can extend current DFE practices to meet these challenges. The final chapter provides a concise summary of the entire book.

Checklist for Getting Started with DFE

Business Motivations

- Do we have one or more business units for whom DFE appears to be a competitive factor?
- Have our customers expressed strong concerns about the environmental performance of our products or manufacturing operations?
- Do we envision regulatory changes or new standards that will influence our ability to profitably produce, distribute and support our products?
- Do environmental excellence and sustainability have a strong influence upon our company reputation or brand image?

Environmental Posture

- Do our corporate responsibility policy and mission statement support the practice of DFE?
- Are we prepared to shift from a compliance-driven to a pro-active environmental management strategy (or have we already done so)?
- Have we established corporate or divisional environmental, health and safety, and/or sustainability improvement goals?
- How might our DFE initiative relate to existing environmental responsibility programs (e.g., Responsible Care®)?

Organization Characteristics

- Are we planning (or have we begun) to implement an environmental management system (EMS) that is integrated with our existing management systems?
- Do we practice concurrent or simultaneous engineering in our new product development, using cross-functional teams?
- Do we have a system for managing product and process quality that can be extended to incorporate environmental attributes?
- Do we have the right organizational resources in line positions to support environmental and product stewardship?

Checklist for Getting Started with DFE *(continued)*

- Do we have appropriate accountability and reward systems to provide incentives for meeting environmental improvement goals?

Existing Experience

- What accomplishments have we made in "green" design, and what practical issues and barriers have we encountered?
- Have we performed any life-cycle assessments for products and/or facilities?
- Have we established programs and expertise in material recycling, resource conservation, waste reduction, or asset recovery?
- Have we implemented any initiatives in pollution prevention and environmentally conscious manufacturing?
- Have we attempted to introduce environmental performance measurement and management systems into our operations?
- Have we developed any useful enabling technologies for DFE, such as computer-based modeling or decision support tools?

Strategic Opportunities

- Can we describe a business case that indicates DFE will contribute to our profitability or business development?
- Can we identify desirable environmental improvements in specific products or processes?
- Have we considered key partnerships or alliances with suppliers or customers that are needed to pursue DFE opportunities?
- Is it valuable for us to enhance environmental awareness among our employees, customers, suppliers, communities, or other stakeholders?
- Are we prepared to move toward life-cycle environmental accounting systems that use an activity-based structure to reveal "true" costs and benefits?

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