6.1: Green Supply Chains

Learning Objectives

1. Learn the definition of a green supply chain.
2. Understand how integration of green and sustainability knowledge can improve the performance of supply chains.
3. Define reverse logistics, life cycle assessment, and design for environment in the context of supply chains.
4. Gain insight into the strategic value of greening your supply chain.


**Green supply chains (GSCs)** became *Supply Chain Digest*’s number one supply-chain trend of 2006 as more companies such as Walmart embraced them. Dan Gilmore, “Top Ten Supply Chain Trends of 2006,” *Supply Chain Digest*, January 4, 2006, accessed January 10, 2011, [http://www.scdigest.com/assets/FirstThoughts/07-01-04.cfm?cid=871&ctype=content](http://www.scdigest.com/assets/FirstThoughts/07-01-04.cfm?cid=871&ctype=content). Fully developed green supply chains consider sustainability for every participant at every step, from design to manufacture, transportation, storage, and use to eventual disposal or recycling. This attentiveness would reduce waste, mitigate legal and environmental risks, minimize and possibly eliminate adverse health impacts throughout the value-added process, improve the reputations of companies and their products (enhancing brands), and enable compliance with increasingly stringent regulations and societal expectations. Thus GSCs offer the opportunity to boost efficiency, value, and access to markets through improving a company’s environmental, social, and economic performance.

![Conventional Supply Chain](https://biz.libretexts.org/Bookshelves/Business/Advanced_Business/Book%3A_Sustainability%2C_Innovation%2C_and_Entrepreneurship%2C_Learning_Option%2C_Business_and_Sustainability/Chapter%3A_Sustainable_Business/Section%3A_Sustainable_Business/figure6.1.png)

**Figure 6.1:** The Conventional Supply Chain

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### Improving Conventional Supply Chains

In its simplest form, a conventional supply chain assumes that firms take raw materials at the beginning of the supply chain and transform them into a product at the end of the supply chain. Ultimately, the supply chain terminates at the point of the final buyer purchasing and using the product (see [Figure 6.1 “The Conventional Supply Chain”](https://biz.libretexts.org/Bookshelves/Business/Advanced_Business/Book%3A_Sustainability%2C_Innovation%2C_and_Entrepreneurship%2C_Learning_Option%2C_Business_and_Sustainability/Chapter%3A_Sustainable_Business/Section%3A_Sustainable_Business/figure6.1.png)). Vertical integration absorbs steps in the supply chain within a single corporation that conducts exchange through internal transfer pricing agreements. Disaggregation maintains ownership in discrete businesses that determine prices through market-based transactions.

A company that sells a final product must meet certain requirements and interact with suppliers, third-party logistics providers, and other stakeholder groups that can influence the entire process. Each institution tries to shape the supply chain to its own advantage. As the product moves from design to consumption (black arrows), waste and other problems (gray arrows) accrue. Whether those problems are unfair wages, deforestation, or air pollution, these costs are not necessarily reflected in the price of the finished product but are instead externalized to the public in some fashion or expected to be borne by intermediate links in the conventional chain.

While the term *supply chain* implies a one-way, linear relationship among participants (e.g., from concept, to resource extraction, to processing, to component manufacturing, to system integration, to final assembly, etc.), the chain is more accurately described as a *network* of individuals and organizations. Managing such networks can become quite
complex, especially as they sprawl over more of the globe. Conventional supply-chain management plans, implements, and controls the operations of the supply chain as efficiently as possible—typically, however, from a limited vantage point that ignores and externalizes many costs.

In contrast, a green supply chain takes a broader, systems view that internalizes some of these costs and ultimately turns them into sources of value. Green supply chains thus modify conventional supply chains in two significant ways: they increase sustainability and efficiency in the existing forward supply chain and add an entirely new reverse supply chain (see Figure 6.2 "The Green Supply Chain").

![Figure 6.2: The Green Supply Chain](https://biz.libretexts.org/Bookshelves/Business/Advanced_Business/Book%3A_Sustainability%2C_Innovation%2C_and_Entre…)

**Improving Logistics**

A company can select various ways to improve the sustainability of its logistics systems. The company may communicate sustainability standards backward to suppliers and require them to adopt environmental management systems or certifications, such as ISO 14001; survey and monitor suppliers’ current practices or products for their sustainability and offer training, technology, and incentives to improve those practices or products; According to the International Organization for Standardization, which established this qualification, ISO 14001 “gives the requirements for quality management systems [and] is now firmly established as the globally implemented standard for providing assurance about the ability to satisfy quality requirements and to enhance customer satisfaction in supplier–customer relationships.” International Organization for Standardization, "ISO 14001:2004," accessed January 10, 2011, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=31807, require suppliers to avoid certain hazardous ingredients and label others; and/or ask suppliers and other supporting firms, such as transportation companies, to suggest ways to improve the efficiency and sustainability of the whole process. Hence companies “greening” their supply chains are likely to communicate and collaborate more with suppliers and subcontractors to innovate and find the best solutions. They might also reach out to nongovernmental organizations (NGOs) and government agencies for further assistance.


Surprisingly, the production changes did not just reduce DesignTex’s environmental impact; they also added value: The factory’s effluent became cleaner than the incoming water supply. Regulatory paperwork was eliminated. Workers no longer needed protective masks or gloves, which eliminated health risks and liability exposure. William McDonough and Michael Braungart, “Waste Equals Food,” in *Cradle to Cradle: Remaking the Way We Make Things* (New York: North Point Press, 2002). Because of these decreased costs and the tax relief for the accompanying environmental investments, the innovation showed a payback period of only five years. Matthew M. Mehalik, “Sustainable Network Design: A Commercial Fabric Case Study,” *Interfaces: International Journal of the Institute for Operations Research and the Management Sciences* 30, no. 3 (May/June 2000): 180–89. It also was an early, successful illustration of cradle-to-cradle design, the cyclical design protocol that allows biologically benign products to safely return to nature.

**Reverse Logistics**

In addition to dramatically improving conventional supply-chain logistics, green supply chains extend past the point of product use, where conventional chains end, and consider how to recover and reuse materials—questions of reverse logistics. Many companies already have rudimentary reverse logistics systems to deal with customers’ returns of items they do not want or that were found defective or otherwise unsatisfactory. An expanded reverse logistics system would ultimately replace the linearity of most production methods—raw materials, to processing, to further conversions and modification, to ultimate product, to use, to disposal—with a cradle-to-cradle, cyclical path or closed loop that begins with the return of used, outmoded, out-of-fashion, and otherwise “consumed” products. The products are either recycled and placed back into the manufacturing stream or broken down into compostable materials. The cycle is never ending because materials return to the land in safe molecular structures (taken up and used by organisms as biological nutrients) or are perpetually used within the economy as input for new products (technical nutrients).


Once collected, whether by the original manufacturer or a third party, the products could be inspected and sorted. Some items might return quickly to the supply chain with only minimal repair or replacement of certain components, whereas other products might need to be disassembled, remanufactured, or cannibalized for salvageable parts while the remnant
is recycled or sent to a landfill or incinerator. “Companies that remanufacture are estimated to save 40–60 percent of the cost of manufacturing a completely new product...while requiring only 20 percent of the effort,” leading to significant, structural savings, wrote Shad Dowlatshahi in *Interfaces*. Shad Dowlatshahi, “Developing a Theory of Reverse Logistics,” *Interfaces: International Journal of the Institute for Operations Research and the Management Sciences* 30, no. 3 (May/June 2000): 144. Moreover, the reverse supply chain might spawn new suppliers as well as other sources of revenue for companies that engage in collection, disassembly, and so on, making the entire network more efficient. Joy M. Field and Robert P. Sroufe, “The Use of Recycled Materials in Manufacturing: Implications for Supply Chain Management and Operations Strategy,” *International Journal of Production Research* 45, no. 18–19 (October 2007): 4439–63. This concept of an eco-efficient closed loop thereby makes green supply chains a central piece of sustainable industrial ecosystems.

**Life-Cycle Assessment and Design for Environment**

The same techniques that improve the sustainability of conventional logistics also aid reverse logistics. In addition, green supply chains fundamentally require two tools: life-cycle assessment (LCA) and design for environment (DfE). According to the US Environmental Protection Agency’s National Risk Management Research Laboratory, LCA takes the viewpoint of a product, process, or service by “(1) compiling an inventory of relevant energy and material inputs and environmental releases; (2) evaluating the potential environmental impacts associated with identified inputs and releases; [and] (3) interpreting the results to help you make an informed decision,” typically to minimize negative impacts across the entire life of the product. US Environmental Protection Agency, “Life-Cycle Assessment (LCA),” accessed January 10, 2011, [http://www.epa.gov/ORD/NRMRL/lcaccess](http://www.epa.gov/ORD/NRMRL/lcaccess). For examples, see Maurizio Bevilacqua, Filippo Emanuele Ciarapica, and Giancarlo Giacchetta, “Development of a Sustainable Product Lifecycle in Manufacturing Firms: A Case Study,” *International Journal of Production Research* 45, no. 18–19 (2007): 4073–98, as well as Stelvia Matos and Jeremy Hall, “Integrating Sustainable Development in the Supply Chain: The Case of Life Cycle Assessment in Oil and Gas and Agricultural Biotechnology,” *Journal of Operations Management* 25, no. 6 (2007): 1083–82. This analysis helps identify the points in the green supply chain that detract from ultimate sustainability and establishes a baseline for improvement. For example, Walmart’s third-party logistics provider in Canada began using railways more than roads to supply ten stores, thereby cutting carbon emissions by 2,600 tons. The company estimated it would save another $4.5 million and prevent 1,400 tons of waste annually by switching from cardboard to plastic shipping crates. “Wal-Mart’s ‘Green’ Campaign Pays Off in Canada,” *DC Velocity*, October 1, 2007, accessed October 2, 2009, [www.dcvelocity.com/news/?article_id=1338](http://www.dcvelocity.com/news/?article_id=1338).

Application of DfE acknowledges that design determines a product’s materials and the processes by which the product is made, shipped, used, and recovered. Hence DfE could be used to avoid toxic materials from the outset; minimize energy and material inputs; and facilitate disassembly, repair, and remanufacturing. For instance, Hewlett Packard (HP) used DfE “product stewards,” whose role, HP explained, was as follows: “[Product stewards] are integrated into product design and research and development teams to identify, prioritize, and recommend environmental design innovations to make products easier to disassemble and recycle. Such features include modular designs, snap-in features that eliminate the need for glues and adhesives, fewer materials, and molded-in colors and finishes instead of paint, coatings, or plating.” Hewlett-Packard, “HP to Eliminate Brominated Flame Retardants from External Case Parts of All New HP Brand Products,” news release, November 1, 2005, accessed January 11, 2011, [http://www.hp.com/hpinfo/newsroom/press/2005/051101a.html](http://www.hp.com/hpinfo/newsroom/press/2005/051101a.html).
Conversely, process designs could influence product designs through new technology that implements an innovative idea. For example, in the Walden Paddlers case discussed in Section 4.5 "Adaptive Collaboration through Value-Added Networks", Hardigg Industries was a plastics-molding company that partnered with Clearvue Plastics to create plastic pellets with 50 percent recycled content, which Hardigg thought was impossible until it was encouraged by the entrepreneurial founder of Walden Paddlers. Later, Hardigg was able to change its rotomolding technology to allow for the use of 100 percent recycled resins. Through the use of recycled materials and Clearvue’s innovation, Hardigg was able to lower costs, establish a competitive advantage within its industry, attract new customers, and increase customer satisfaction.Paul H. Farrow, Richard R. Johnson, and Andrea L. Larson, “Entrepreneurship, Innovation, and Sustainability Strategies at Walden Paddlers, Inc.,” Interfaces: International Journal of the Institute for Operations Research and the Management Sciences 30, no. 3 (May/June 2000): 215–25.

Greener Supply Chains: Accelerating Response to Changed Context

Although green supply chains could present novel challenges, they had spread to address a convergence of legal requirements, consumer expectations, and competition for continued profitability. In 2001, a study of twenty-five suppliers showed 80 percent received significant requests to improve the environmental quality of their operations and products, and they in turn asked their suppliers to do the same.Business for Social Responsibility Education Fund, Suppliers’ Perspectives on Greening the Supply Chain (San Francisco: Business for Social Responsibility Education Fund, 2001), accessed January 11, 2011, www.getf.org/file/toolmanager/O16F15429.pdf. A larger survey from 2008 indicated 82 percent of respondents were planning to implement or were already implementing green supply-chain management strategies.Walfried M. Lassar and Adrian Gonzalez, The State of Green Supply Chain Management: Survey Results (Miami, FL: Ryder Center for Supply Chain Management, Florida International University, 2008), accessed January 11, 2011, grci.calpoly.edu/projects/sustaincommworld/pdfs/WP_Florida_Supply_Chain_Mgmt.pdf. The trend toward green supply chains was expected to continue.


Between 2000 and 2009, the increased emphasis on sustainability expanded the scope further and deeper into environmental, public health, and community/social issues and embraced stakeholders beyond consumers and investors.Charles J. Corbett and Robert D. Klassen, "Expanding the Horizons: Environmental Excellence as Key to Improving Operations," Manufacturing and Service Operations Management 8, no. 1 (Winter 2006): 5–22. This new...


Consumers and institutional investors, meanwhile, have exerted pressure on companies through a variety of tactics from socially responsible investment screening criteria to market campaigns for engaging in fair trade or ending sweatshop labor. Failure to publicly improve practices anywhere along the supply chain could hurt brand image and curtail access to markets. American universities and colleges founded the Worker Rights Consortium in 2000 “to assist universities with the enforcement of their labor rights codes of conduct, which were adopted to protect the rights of workers producing apparel and other goods bearing university names and logos.” Worker Rights Consortium, “Mission: History,” accessed October 2, 2009, [www.workersrights.org/about/history.asp](http://www.workersrights.org/about/history.asp). Manufacturers such as Canada’s Hudson Bay Company began to audit suppliers’ factories for compliance with labor standards. Tim Reeve and Jasper Steinhausen, “Sustainable Suppliers, Sustainable Markets,” *CMA Management* 81, no. 2 (April 2007): 30–33. By 2005, the Investor Environmental Health Network, following the effective strategy of institutional investors negotiating with companies for more action and accountability on climate change, was encouraging investment managers and corporations to reduce high-risk toxic chemicals used in their products and used by companies in which they invest.
Successful Green Supply Chains Manage Added Complexity


Reverse supply chains complicate the overall supply chain, and therefore they need to be carefully crafted and considered in overall product design, production, and distribution. Materials and components recovered from used products need to reenter the same forward supply chain as new materials or components. Hence companies must recover items efficiently, train employees or subcontractors to assess properly the condition of a recovered item and what is salvageable and what is not, and manage their inventory to even out variation in the rate and quality of returned items.

V. Daniel R. Guide Jr., Vaidyanathan Jayaraman, Rajesh Srivastava, and W. C. Benton, “Supply-Chain Management for Recoverable Manufacturing Systems,” *Interfaces: International Journal of the Institute for Operations Research and the Management Sciences* 30, no. 3 (May/June 2000): 125–42; also Nils Rudi, David F. Pyke, and Per Olav Sporsheim, “Product Recovery at the Norwegian National Insurance Administration,” *Interfaces: International Journal of the Institute for Operations Research and the Management Sciences* 30, no. 3 (May/June 2000): 166–79. They must also balance the availability of salvaged components or recycled materials with the need for new components or materials, especially as certain proprietary parts become unavailable or production processes change. In cases when consumers may want the same item they had before with only minor changes, such as a vehicle, businesses will also have to track individual pieces through disassembly and refurbishment.


After establishing a green supply chain, companies need to assess its performance. In their 2008 survey of seventy supply-chain executives, Lassar and Gonzalez noted, “Almost 40 percent of the 56 firms that are active with green activities do not have any metrics to measure green/sustainability results in their firms.” Walfried M. Lassar and Adrian Gonzalez, *The State of Green Supply Chain Management: Survey Results* (Miami, FL: Ryder Center for Supply Chain Management, Florida International University, 2008), accessed January 11, 2011, grci.calpoly.edu/projects/sustaincommworld/pdfs/WP_Florida_Supply_Chain_Mgmt.pdf. Companies with metrics tracked quantities such as fuel use, packaging, and so on. Another study corroborates this trend: what metrics companies do have tend to cluster around eco-efficiency indicators, such as packaging used or miles traveled, likely because those are the easiest to observe, quantify, and associate with specific actions. Vesela Veleva, Maureen Hart, Tim Greiner, and Cathy Crumbley, “Indicators for Measuring Environmental Sustainability,” *Benchmarking* 10, no. 2 (2003): 107–19. Companies can, however, include broader measures such as customer satisfaction. However, even then a company may fall short. A systems, health-oriented, and green approach to design does not always work. Some view Frito-Lay’s SunChips compostable bag (offered to the market consistent with biodegradable bags being the fastest growing segment in packaging) as having failed due to its loud noise when handled. Since the crinkling of the bags at up to eighty-five decibels is comparable to glass breaking or an engine revving, the company has gone back to the drawing board with this packaging design.

### Fading Extrinsic Challenges

Finally, green supply chains had to overcome institutional inertia and confusion. First, large companies with financial and political resources tended to resist change, especially at the outset, because of the large capital and infrastructural investments in the status quo. Walmart’s green initiative, however, appears to be the turning point that moves other large enterprises toward green supply chains.

Second, in 2009, no official criteria defined a green supply chain. Standards such as ISO 14000 usually focus on a
single entity and not the supply chain, while legal requirements often focus on products and ingredients. ISO 14001, the core voluntary set of standards, is used by firms to design an environmental management system that provides internal monitoring and provides practices, procedures, and tools for systematic efforts to improve performance. However, nothing defines how much of the supply chain is required to have ISO 14000 or other certifications to qualify for the green supply chain label. When Home Depot solicited its suppliers for candidates to its Eco Options marketing campaign, one manufacturer praised the plastic handles of its paintbrushes as more environmentally sensitive than wooden handles, while another praised the wooden handles of its paintbrushes as environmentally better than plastic. Clifford Krauss, “At Home Depot, How Green Is That Chainsaw?” New York Times, June 25, 2007, accessed January 11, 2011, http://www.nytimes.com/2007/06/25/business/25depot.html?_r=1.

The lack of standards could promote individual certification programs, such as the cradle-to-cradle certification provided by McDonough Braungart Design Chemistry, LLC, which implies a corresponding green supply chain. This program, however, is private, largely to protect the confidential business information of its clients to ensure their cooperation, and has therefore been criticized for its lack of transparency. Danielle Sacks, “Green Guru William McDonough Must Change, Demand His Biggest Fans,” Fast Company, February 26, 2009, accessed January 11, 2011, http://www.fastcompany.com/blog/danielle-sacks/ad-verse-effect/william-mcdonough-must-change; Diana den Held, “’Criticism on Cradle to Cradle? Right on Schedule,’ Says Michael Braungart,” Duurzaam Gebouwd (blog), March 20, 2009, accessed October 2, 2009, www.duurzaamgebouwd.nl/index.php?pageID=3946&messageID=1936. However, the cradle-to-cradle approach is now being explored in California as a statewide system to encourage safer, less polluting design protocols. In the worst cases, vague standards or opaque processes can lead to charges of “greenwashing,” or exaggerating or fabricating environmental credentials. Melissa Whellams and Chris MacDonald, “What Is Greenwashing, and Why Is It a Problem?” Business Ethics, accessed October 2, 2009, http://www.businessethics.ca/greenwashing.

Greenwashing distracts people who are serious about taking care of the environment with counterproductive activities, misinforms the public, and undermines the credibility of more substantial initiatives of others.

Nonetheless, resistance to change and lack of an official definition reflect extrinsic problems rather than problems intrinsic to the mechanics of green supply chains. Such problems are more about marketing than about function. As green supply chains prove themselves through superior performance, they will likely become more studied, better understood and defined, and more widely spread. Good starting points for firms that understand these issues as strategic are to look at the inherent risks of not examining their supply chains and to envision a future market position in which a green, differentiated product and brand will grow revenues.

Green Supply Chains Improve Performance

Green supply chains yield a wide range of benefits. They can reduce a company’s negative environmental or social impact, decrease operating costs, increase customer service and sales, promote innovation, and mitigate regulatory risk. The most immediate benefits of green supply chains are reduced environmental harm and operations costs. For example, Fuji Xerox adopted a cradle-to-cradle philosophy that emphasized supporting document services over a life cycle rather than selling photocopiers and forgetting about them. Fuji Xerox leased equipment and recovered 99 percent of materials from used equipment in Asia in 2006, saving $13 million on new materials, generating an additional $5.4 million in revenue, and reducing raw material consumption by 2,000 tons at its factories in China. Fuji Xerox Australia, “Fuji Xerox Innovation Makes Business and Environmental Sense,” news release, September 25, 2007, accessed January 11, 2011, http://www.fujixerox.com.au/about/media/articles/546. Government institutions could also benefit.

Another benefit from green supply chains was increased innovation, largely because people worked together who had not done so before, or new challenges brought new answers. By collaborating with suppliers and designers to design its cradle-to-cradle system, Fuji Xerox saw the opportunity to make material and component improvements. The decision was made to redesign a spring and a roller, saving the US affiliate approximately $40 million annually. *Corporate Societal Responsibility: Knowledge Learning through Sustainable Global Supply Chain Management*, p 14, accessed April 2, 2011, www.reman.org/pdf/Fuji-Xerox.pdf.

Moreover, green supply chains can lead to improved customer satisfaction and higher sales. Through product recovery programs, Dell increased sales and strengthened its brand reputation for customer satisfaction and corporate citizenship. Dell Asset Recovery Services (ARS) designed a customized solution that quickly recovered 2,300 servers from the Center for Computational Research at the University at Buffalo, SUNY. “That solves two problems for us,” said SUNY’s Tom Furlani. “It helps get rid of the old equipment in a cost-effective way, and it allows us to get new, faster equipment that is under warranty.” In addition to secure destruction of hard drive data, the Dell ARS maintains a zero landfill policy and a zero trash export policy. Unwanted equipment is disassembled into materials that reenter the manufacturing stream. Dell, *That’s Refreshing*, case study, November 2006, accessed January 11, 2011, www.dell.com/downloads/global/services/suny_ars_casesystudy.pdf. This step also placed Dell in a more favorable position with the Basel Action Network, an NGO that targeted the company as contributing to e-waste exports to emerging economies.


**Conclusion**

Green supply chains have arisen in response to multiple, often interwoven problems: environmental degradation, rising prices for energy and raw materials, and global supply chains that link labor and environmental standards in one country with legal and consumer expectations in another. Green supply chains strive to ensure that value creation, rather than
risk and waste, accumulates at each step from design to disposal and recovery. They have gained audience with large and small organizations across cultures, regions, and industries. Managing complex relationships and flows of materials across companies and cultures may pose a key challenge for green supply chains. Nonetheless, those challenges are not insurmountable, and the effort to green a supply chain can provide significant benefits.

KEY TAKEAWAY

- Green and sustainability thinking can improve supply-chain management to save money, improve products, and enhance brands.

EXERCISES

1. Select a common product and identify the many inputs and stages in its production that were required to deliver it to your hands.
2. Now analyze ways to “green” that supply chain; try to think of every possible way to apply sustainability concepts to optimize the supply-chain outcomes.
3. Discuss the barriers you might find in implementing that supply-chain strategy with real suppliers.
4. Go to the Green Design Institute at Carnegie Mellon University (http://www.eiolca.net) and explore the LCA method.