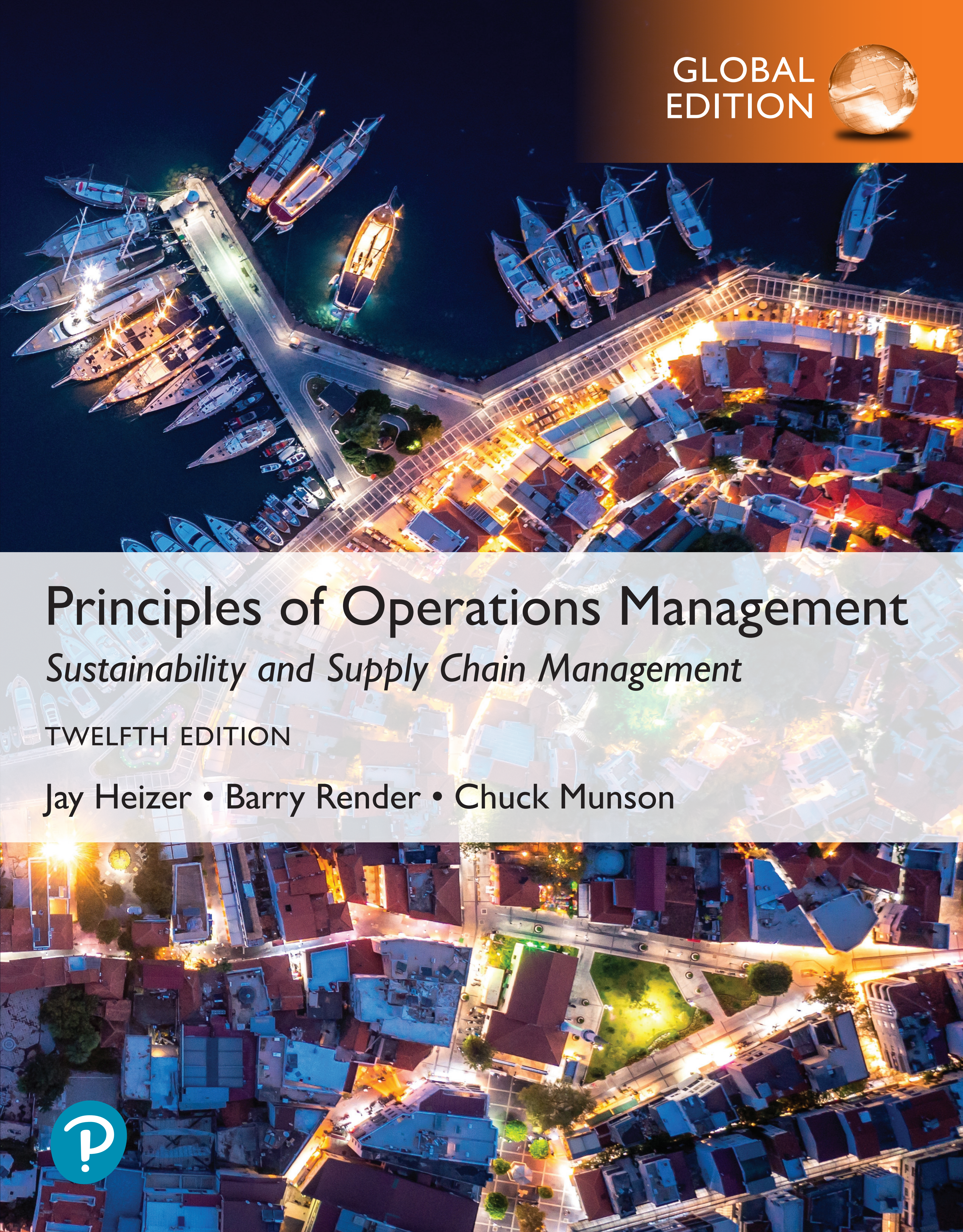

GLOBAL EDITION

# Principles of Operations Management

*Sustainability and Supply Chain Management*

TWELFTH EDITION

Jay Heizer • Barry Render • Chuck Munson

# Digital Resources for Students

Your new textbook provides 12-month access to digital resources that may include Excel data files, online tutorials, and problem-solving software for end-of-chapter problems in this text. Refer to the preface in the textbook for a detailed list of resources.

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## Example S1

### DESIGN FOR DISASSEMBLY

Sound Barrier, Inc., needs to decide which of two speaker designs is better environmentally.

**APPROACH ▶** The design team collected the following information for two audio speaker designs, the *Harmonizer* and the *Rocker:*

1. Resale value of the components minus the cost of transportation to the disassembly facility
2. Revenue collected from recycling
3. Processing costs, which include disassembly, sorting, cleaning, and packaging
4. Disposal costs, including transportation, fees, taxes, and processing time

**SOLUTION ▶** The design team developed the following revenue and cost information for the two speaker design alternatives:

**LO S5.4** *Calculate* design for disassembly

**Harmonizer**

| PART | RESALE REVENUE PER UNIT | RECYCLING REVENUE PER UNIT | PROCESSING COST PER UNIT | DISPOSAL COST PER UNIT |
|---|---|---|---|---|
| Printed circuit board | $5.93 | $1.54 | $3.46 | $0.00 |
| Laminate back | 0.00 | 0.00 | 4.53 | 1.74 |
| Coil | 8.56 | 5.65 | 6.22 | 0.00 |
| Processor | 9.17 | 2.65 | 3.12 | 0.00 |
| Frame | 0.00 | 0.00 | 2.02 | 1.23 |
| Aluminum case | 11.83 | 2.10 | 2.98 | 0.00 |
| Total | $35.49 | $11.94 | $22.33 | $2.97 |

**Rocker**

| PART | RESALE REVENUE PER UNIT | RECYCLING REVENUE PER UNIT | PROCESSING COST PER UNIT | DISPOSAL COST PER UNIT |
|---|---|---|---|---|
| Printed circuit board | $7.88 | $3.54 | $2.12 | $0.00 |
| Coil | 6.67 | 4.56 | 3.32 | 0.00 |
| Frame | 0.00 | 0.00 | 4.87 | 1.97 |
| Processor | 8.45 | 4.65 | 3.43 | 0.00 |
| Plastic case | 0.00 | 0.00 | 4.65 | 3.98 |
| Total | $23.00 | $12.75 | $18.39 | $5.95 |

Using the Equation (S5-1), the design team can compare the two design alternatives:

Revenue retrieval =
Total resale revenue + Total recycling revenue − Total processing cost − Total disposal cost (S5-1)

Revenue retrieval for Harmonizer = \$35.49 + \$11.94 − \$22.33 − \$2.97 = \$22.13

Revenue retrieval for Rocker = \$23.00 + \$12.75 − \$18.39 − \$5.95 = \$11.41

**INSIGHT ▶** After analyzing both environmental revenue and cost components of each speaker design, the design team finds that the Harmonizer is the better environmental design alternative because it achieves a higher revenue retrieval opportunity. Note that the team is assuming that both products have the same market acceptance, profitability, and environmental impact.

**LEARNING EXERCISE ▶** What would happen if there was a change in the supply chain that caused the processing and disposal costs to triple for the laminate back part of the Harmonizer? [Answer: The revenue retrieval from the Harmonizer is \$35.49 + \$11.94 − \$31.39 − \$6.45 = \$9.59. This is less than the Rocker's revenue retrieval of \$11.41, so the Rocker becomes the better environmental design alternative, as it achieves a higher revenue retrieval opportunity.]

**RELATED PROBLEMS ▶** S5.1, S5.2, S5.3, S5.9, S5.12, S5.13, S5.14

## Production Process

Manufacturers look for ways to reduce the amount of resources in the production process. Opportunities to reduce environmental impact during production typically revolve around the themes of energy, water, and environmental contamination. Conservation of energy and improving energy efficiency come from the use of alternative energy and more energy-efficient machinery. For example:

- S.C. Johnson built its own power plant that runs on natural gas and methane piped in from a nearby landfill, cutting back its reliance on coal-fired power.
- PepsiCo developed *Resource Conservation (ReCon)*, a diagnostic tool for understanding and reducing in-plant water and energy usage. In its first 2 years, *ReCon* helped sites across the world identify 2.2 billion liters of water savings, with a corresponding cost savings of nearly $2.7 million.
- Frito-Lay decided to extract water from potatoes, which are 80% water. Each year, a single factory processes 350,000 tons of potatoes, and as those potatoes are processed, the company reuses the extracted water for that factory's daily production.

**STUDENT TIP** Las Vegas, always facing a water shortage, pays residents $40,000 an acre to take out lawns and replace them with rocks and native plants.

These and similar successes in the production process reduce both costs and environmental concerns. Less energy is consumed, and less material is going to landfills.

## Logistics

As products move along in the supply chain, managers strive to achieve efficient route and delivery networks, just as they seek to drive down operating costs. Doing so reduces environmental impact. Management analytics (such as linear programming, queuing, and vehicle routing software) help firms worldwide optimize elaborate supply-chain and distribution networks. Networks of container ships, airplanes, trains, and trucks are being analyzed to reduce the number of miles traveled or the number of hours required to make deliveries. For example:

- UPS has found that making left turns increases the time it takes to make deliveries. This in turn increases fuel usage and carbon emissions. So UPS plans its delivery truck routes with the fewest possible left turns. Likewise, airplanes fly at different altitudes and routes to take advantage of favorable wind conditions in an effort to reduce fuel use and carbon emissions.
- Food distribution companies now have trucks with three temperature zones (frozen, cool, and nonrefrigerated) instead of using three different types of trucks.
- Whirlpool radically revised its packaging to reduce "dings and dents" of appliances during delivery, generating huge savings in transportation and warranty costs.

To further enhance logistic efficiency, operations managers also evaluate equipment alternatives, taking into account cost, payback period, and the firm's stated environmental objectives. Example S2 deals with decision making that takes into account life cycle ownership costs. A firm must decide whether to pay *more* up front for vehicles to further its sustainability goals or to pay *less* up front for vehicles that do not.

### Example S2

#### LIFE CYCLE OWNERSHIP AND CROSSOVER ANALYSIS

Blue Star is starting a new distribution service that delivers auto parts to the service departments of auto dealerships in the local area. Blue Star has found two light-duty trucks that would do the job well, so now it needs to pick one to perform this new service. The Ford TriVan costs $28,000 to buy and uses regular unleaded gasoline, with an average fuel efficiency of 24 miles per gallon. The TriVan has an operating cost of $.20 per mile. The Honda CityVan, a hybrid truck, costs $32,000 to buy and uses regular unleaded gasoline and battery power; it gets an average of 37 miles per gallon. The CityVan has an operating cost of $.22 per mile. The distance traveled annually is estimated to be 22,000 miles, with the life of either truck expected to be 8 years. The average gas price is $4.25 per gallon.

**APPROACH ▶** Blue Star applies Equation (S5-2) to evaluate total life cycle cost for each vehicle:

$$\text{Total life cycle cost} = \text{Cost of vehicle} + \text{Life cycle cost of fuel} + \text{Life cycle operating cost} \quad \text{(S5-2)}$$

a) Based on life cycle cost, which model truck is the best choice?
b) How many miles does Blue Star need to put on a truck for the costs to be equal?
c) What is the crossover point in years?

**SOLUTION ▶**

a) Ford TriVan:

$$\text{Total life-cycle cost} = \$28{,}000 + \left[\frac{22{,}000\,\frac{miles}{year}}{24\,\frac{miles}{gallon}}\right](\$4.25\ /\ gallon)(8\ years) + \left(22{,}000\,\frac{miles}{year}\right)(\$.20\ /\ mile)(8\ years)$$

$$= \$28{,}000 + \$31{,}167 + \$35{,}200 = \$94{,}367$$

Honda CityVan:

$$\text{Total life-cycle cost} = \$32{,}000 + \left[\frac{22{,}000\,\frac{miles}{year}}{37\,\frac{miles}{gallon}}\right](\$4.25\ /\ gallon)(8\ years) + \left(22{,}000\,\frac{miles}{year}\right)(\$.22\ /\ mile)(8\ years)$$

$$= \$32{,}000 + \$20{,}216 + \$38{,}720 = \$90{,}936$$

b) Blue Star lets $M$ be the crossover (break-even) point in miles, sets the two life cycle cost equations equal to each other, and solves for $M$:

Total cost for Ford TriVan = Total cost for Honda CityVan

$$\$28{,}000 + \left[\frac{4.25\,\frac{\$}{gallon}}{24\,\frac{miles}{gallon}} + .20\,\frac{\$}{mile}\right](M\ miles) = \$32{,}000 + \left[\frac{4.25\,\frac{\$}{gallon}}{37\,\frac{miles}{gallon}} + .22\,\frac{\$}{mile}\right](M\ miles)$$

or,

$$\$28{,}000 + \left(.3770\,\frac{\$}{mile}\right)(M) = \$32{,}000 + \left(.3349\,\frac{\$}{mile}\right)(M)$$

or,

$$\left(.0421\,\frac{\$}{mile}\right)(M) = \$4{,}000$$

$$M = \frac{\$4{,}000}{.0421\,\frac{\$}{mile}} = 95{,}012\ miles$$

c) The crossover point in years is:

$$\text{Crossover point} = \frac{95{,}012\ miles}{22{,}000\,\frac{miles}{year}} = 4.32\ years$$

**INSIGHTS ▶**

a) Honda CityVan is the best choice, even though the initial fixed cost and variable operating cost per mile are higher. The savings comes from the better fuel mileage (more miles per gallon) for the Honda CityVan.
b) The crossover (break-even) point is at 95,012 miles, which indicates that at this mileage point, the cost for either truck is the same.

c) It will take 4.32 years to recoup the cost of purchasing and operating either vehicle. This is the point of indifference between the two vehicles. However, it will cost Blue Star approximately $.03 per mile less to operate the Honda CityVan than the Ford TriVan over the 8-year expected life.

**LEARNING EXERCISE ▶** If the cost of gasoline drops to $3.25, what will be the total life-cycle cost of each van, the break-even point in miles, and the crossover point in years? [Answer: The cost of the Ford TriVan is $87,033; the Honda CityVan costs $86,179; the crossover point in miles is 144,927; and the crossover point in years is 6.59.]

**RELATED PROBLEMS ▶** S5.4, S5.5, S5.6, S5.10, S5.11, S5.15, S5.16, S5.17, S5.18, S5.19

## End-of-Life Phase

We noted earlier that during product design, managers need to consider what happens to a product or its materials after the product reaches its end-of-life stage. Products with less material, with recycled material, or with recyclable materials all contribute to sustainability efforts, reducing the need for the "burn or bury" decision and conserving scarce natural resources.

**Closed-loop supply chains**
Supply chains that consider forward and reverse product flows over the entire life cycle.

Innovative and sustainability-conscious companies are now designing **closed-loop supply chains**, also called *reverse logistics*. Firms can no longer sell a product and then forget about it. They need to design and implement end-of-life systems for the physical return of products that facilitate recycling or reuse.

Caterpillar, through its expertise in remanufacturing technology and processes, has devised *Cat Reman,* a remanufacturing initiative, in an effort to show its commitment to sustainability. Caterpillar remanufactures parts and components that provide same-as-new performance and reliability at a fraction of new cost, while reducing the impact on the environment. The remanufacturing program is based on an exchange system where customers return a used component in exchange for a remanufactured product. The result is lower operating costs for the customer, reduced material waste, and less need for raw material to make new products. In a 1-year period, Caterpillar took back 2.1 million end-of-life units and remanufactured more than 130 million pounds of material from recycled iron.

The *OM in Action* box, "Designing for End of Life," describes Apple's design philosophy to facilitate the disassembly, recycling, and reuse of its iPhones that have reached their end of life.

# Regulations and Industry Standards

**LO S5.5** *Explain* the impact of sustainable regulations on operations

Government, industry standards, and company policies are all important factors in operational decisions. Failure to recognize these constraints can be costly. Over the last 100 years, we have seen development of regulations, standards, and policies to guide managers in product design, manufacturing/assembly, and disassembly/disposal.

To guide decisions in *product design*, U.S. laws and regulations, such as those of the Food and Drug Administration, Consumer Product Safety Commission, and National Highway Safety Administration, provide guidance and often explicit regulations.

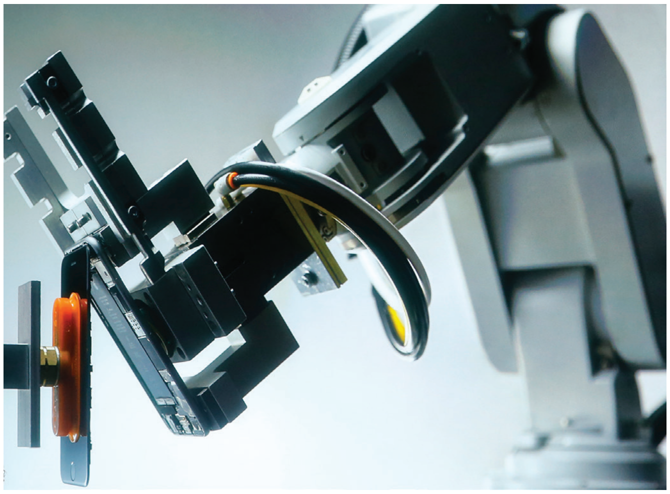
*Manufacturing and assembly activities* have their own set of regulatory agencies providing guidance and standards of operations. These include the Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), and many state and local agencies that regulate workers' rights and employment standards.

**STUDENT TIP**
A group of 100 apparel brands and retailers have created the Eco Index to display an eco-value on a tag, like the Energy Star rating does for appliances.

U.S. agencies that govern the *disassembly and disposal of hazardous products* include the EPA and the Department of Transportation. As product life spans shorten due to ever-changing trends and innovation, product designers are under added pressure to *design for disassembly*. This encourages designers to create products that can be disassembled and whose components can be recovered, minimizing impact on the environment.

Organizations are obliged by society and regulators to reduce harm to consumers, employees, and the environment. The result is a proliferation of community, state, federal, and even international laws that often complicate compliance. The lack of coordination of regulations and reporting requirements between jurisdictions adds not just complexity but cost.

## OM in Action — Designing for End of Life[4]


Stephan Lam/REUTERS Pictures

Apple just introduced a piece of technology that will likely never be used by any consumer. Instead, it kind of cleans up after consumers: a robot that breaks down 1.2 million iPhones a year for recycling. The arrival of Liam—a 29-armed robot—addresses a big challenge facing tech manufacturers today. Even as they entice consumers to ditch their existing devices for the next new thing, companies must figure out what to do with the growing number of devices that are destined for the scrapheap. "We think as much now about the recycling and end of life of products as the design of products itself," says Apple's VP of environment, policy and social initiatives.

Other electronics makers take a different recycling approach, designing products that simplify disassembly by replacing glue and screws with parts that snap together, for instance. Some also have reduced the variety of plastics used and avoid mercury and other hazardous materials that can complicate disposal. Samsung designed a recent model of its 55-inch curved television for easier disassembly, eliminating 30 of 38 screws and replacing them with snap closures. Now the TVs can be dismantled in less than 10 minutes.

The constant stream of new devices has contributed to an increase in electronic waste, with its inherent health and environmental risks. A product's design choices for the types of materials and varieties of components are an important part of a successful circular economy.

From the following examples it is apparent that nearly all industries must abide by regulations in some form or another:

- Commercial homebuilders are required not just to manage water runoff but to have a pollution prevention plan for each site.
- Public drinking water systems must comply with the federal Safe Drinking Water Act's arsenic standard, even for existing facilities.
- Hospitals are required to meet the terms of the Resource Conservation and Recovery Act, which governs the storage and handling of hazardous material.

The consequences of ignoring regulations can be disastrous and even criminal. The EPA investigates environmental crimes in which companies and individuals are held accountable. Prison time and expensive fines can be handed down. (British Petroleum paid billions of dollars in fines in the past few years for breaking U.S. environmental and safety laws.) Even if a crime has not been committed, the financial impacts and customer upheaval can be disastrous to companies that do not comply with regulations. Due to lack of supplier oversight, Mattel, Inc., the largest U.S. toymaker, has recalled more than 10 million toys in recent years because of consumer health hazards such as lead paint.

## International Environmental Policies and Standards

Organizations such as the U.N. Framework Convention on Climate Change (UNFCCC), International Organization for Standardization (ISO), and governments around the globe are guiding businesses to reduce environmental impacts from disposal of materials to reductions in greenhouse gas (GHG) emissions. Some governments are implementing laws that mandate the outright reduction of GHG emissions by forcing companies to pay taxes based on the amount of GHG emissions that are emitted. We now provide an overview of some of the international standards that apply to how businesses operate, manufacture, and distribute goods and services.

**European Union Emissions Trading System** The European Union (EU) has developed and implemented the EU Emissions Trading System (EUETS) to combat climate change. This is the key tool for reducing industrial greenhouse gas emissions in the EU. The EUETS works on the "cap-and-trade" principle. This means there is a cap, or limit, on the total amount of certain GHGs that can be emitted by factories, power plants, and airlines in EU airspace. Within this cap, companies receive emission allowances, which they can sell to, or buy from, one another as needed.

**ISO 14001 and 50001** The International Organization for Standardization (ISO) is widely known for its contributions in ISO 9000 quality assurance standards (discussed in Chapter 6). The ISO 14001 and ISO 50001 family grew out of the ISO's commitment to support U.N. and government objectives of sustainable development. ISO 14001 is a series of environmental management standards that contain five core elements: (1) environmental management, (2) auditing, (3) performance evaluation, (4) labeling, and (5) life cycle assessment. The more recently introduced ISO 50001 sets out the criteria for improving energy use, as well as the efficiency and security of energy consumption. These standards are primarily aimed at working toward the reduction of greenhouse gas (carbon dioxide) emissions, while at the same time helping businesses reduce their energy usage and costs. ISO 50001 is designed to work alongside ISO 14001. Its main objective is to help businesses and individuals maintain constant awareness of the need for good energy reduction practices and identify potential energy savings. The ISO standards have several advantages:

**ISO 14001**
A series of environmental management standards established by the International Organization for Standardization (ISO).

**ISO 50001**
Environmental standards for improving energy performance.

- Positive public image and reduced exposure to liability
- Good systematic approach to pollution prevention through minimization of ecological impact of products and activities
- Compliance with regulatory requirements and opportunities for competitive advantage

ISO sustainability standards have been implemented by more than 200,000 organizations in 155 countries. Companies that have done so report environmental and economic benefits such as reduced raw material/resource use, reduced energy consumption, lower distribution costs, improved corporate image, improved process efficiency, reduced waste generation and disposal costs, and better utilization of recoverable resources.

ISO 14001 and ISO 50001 give guidance to companies to minimize harmful effects on the environment caused by their activities. The *OM in Action* box, "Subaru's Clean, Green Set of Wheels with ISO 14001 and ISO 50001," illustrates the growing application of the ISO environmental standards.

## OM in Action — Subaru's Clean, Green Set of Wheels with ISO 14001 and ISO 50001[5]

"Going green" had humble beginnings. First, it was newspapers, soda cans and bottles, and corrugated packaging—the things you typically throw into your own recycling bins. Similarly, at Subaru's Lafayette, Indiana, plant, the process of becoming the first completely waste-free auto plant in North America began with employees dropping these items in containers throughout the plant. Then came employee empowerment. "We had 268 suggestions for different things to improve our recycling efforts," said Denise Coogan, plant ISO environmental compliance leader.

Some ideas were easy to handle. "With plastic shrink wrap, we found some (recyclers) wouldn't take colored shrink wrap. So we went back to our vendors and asked for only clear shrink wrap," Coogan said. Some suggestions were a lot dirtier. "We went dumpster diving to see what we were throwing away and see what we could do with it."

The last load of waste generated by Subaru made its way to a landfill 10 years ago. Since then, everything that enters the plant eventually exits as a usable product. Coogan adds, "We didn't redefine 'zero.' Zero means zero. Nothing from our manufacturing process goes to the landfill."

Last year alone, the Subaru plant recycled 13,142 tons of steel, 1,448 tons of paper products, 194 tons of plastics, 10 tons of solvent-soaked rags, and 4 tons of light bulbs. Doing so conserved 29,200 trees, 670,000 gallons of oil, 34,700 gallons of gas, 10 million gallons of water, and 53,000 million watts of electricity. "Going green" isn't easy, but it can be done!

Cnky Photography/Fotolia