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Environmental Impact: The Big Picture

The planet's population is now approaching 7 billion—an increase of about 5 billion people in just the past five decades—and the total population is likely to increase by another 1 billion people in the next decade. Analysts now expect that the ranks of the middle class (people who may want your products!) will swell by as many as 1.8 billion in the next 12 years.¹

You've probably seen similar projections, and even though you know intellectually that an extra couple of billion people represents a sustainability challenge, it can be hard to relate those huge numbers to your job. So, to make the scale more real, let's work through what it would mean to give the next 1 billion middle-class citizens of the world a single 60-watt incandescent light bulb.

Each bulb weighs about 0.7 ounce, including the packaging, so a billion of them weigh around 20,000 metric tons, or about the same as 15,000 Toyota Prius cars. As an engineer, you know that multiplying anything by 10⁹ makes a big number, but even from this simple case you start to get a feel for how dramatic the scale is in real-world terms.

Next, let's turn on those light bulbs. If they're all on at the same time, they would consume 60,000 megawatts of electricity—and that would require 120 new 500-megawatt power plants to keep them burning. Luckily, our imaginary middle-class consumers will use their light bulbs only four hours per day, so we're down to 10,000 megawatts at any given moment. However, that means we'll still need 20 new 500-megawatt power plants. If coal-fired, each of those plants burns 1.43 million tons of coal per year.²

That doesn't sound like a good idea from an eco perspective, so let's try solar power for our light bulbs. If we use current commercially available solar

technology, we'll need roughly 50 square kilometers of solar panels, or more than one-third the land area of either San Francisco or Boston. Hmmm. So, let's try wind power instead... We'll still need one-tenth of all the wind power produced in the world in 2007, just to keep those new light bulbs on for a few hours a day.

This is the scale we're dealing with when we're talking about a billion consumers of any product or service. Thousands or millions of tons of material. Thousands or millions of megawatts. And it keeps going. Think about the raw materials consumed to make those light bulbs, the energy consumed by commuting factory workers, the packaging materials, the ships and trucks used for distribution, and ultimately, the waste that is involved when we have a billion light bulbs. And if we're having trouble delivering a single light bulb to a billion people sustainably, what happens when these billion people want stoves, refrigerators, TVs, computers, cell phones, radios, and cars? What happens when they want street lights, low-cost air travel, hotels, and restaurants? You get the idea.

As engineers, we are already challenged by the environmental impact of products and services today—and the challenge will continue to grow as the world's economy grows. As a result, the scale of our innovation is going to need to meet the scale of the demand for sustainable products and services. We need innovation on many fronts. Using our earlier example, we need the innovation of the compact fluorescent light bulb, which cuts the number of new plants required from 20 to 5; the innovation of better solar and windgenerated power to help us avoid building those plants at all; and the innovation of better product designs using fewer natural resources and more renewable materials.

Eco-Responsible Engineering: An Enormous Opportunity

While much of the focus of this chapter will discuss the negative impact of products and services, we also want to address the potential for positive environmental impact. You'll see that we frequently use the word *sustainability*. Just as *impact* usually focuses on the damage caused by a product or service, *sustainability* forces us to think forward to the desirable end, to ask ourselves what it would take to have a version that could be delivered in massive volume, at reasonable cost, year after year after year. We also like the term because it opens the door to the economic side. If the cost of crude oil rises to \$200 per barrel, can we still sustainably sell our product? How about

\$300? \$400? What effect would a widespread fresh-water shortage have on our service? So, we're looking not only at product sustainability, but also at business sustainability.

An important focus of this section of the book will be the urgency of our global climate situation and the danger posed by steadily increasing releases of carbon dioxide and other greenhouse gas (GHG) compounds into the atmosphere. We, the authors, are convinced by the data that our society needs to make rapid progress in reducing our GHG emissions, including carbon dioxide (often erroneously shortened to "carbon" in the press), methane, water vapor, and so forth.

But we also see that the same behaviors that are creating massive GHG emissions—reliance on petroleum products for transportation, fossil fuels of all kinds for heating and cooling, and coal for electrical generation—are also responsible for a number of our biggest challenges beyond the environment and climate risks. How do we lower our energy dependence on foreign countries, many of which are historically unstable? How do we maintain a stable and economically acceptable cost for energy? How do we meet the energy demands of large, rapidly growing nations such as China and India at a time when oil production appears to be at or near its peak?

So, while we believe that reducing our GHG emissions is imperative, we also see that successfully doing so could provide huge benefits in other areas.

As you read this section you'll notice that we've broadened the environmental discussion to include more than GHG emissions and their impact on Earth's climate. It is a simple fact that the current model of production, consumption, and waste disposal is not sustainable. We are running out of the key resources that fuel our industrial processes: fossil fuels, clean water, and core elements and materials that we use to make our increasingly complex products. Simply reducing GHG emissions won't be enough. We also need to make progress on our other sustainability challenges.

Engineering—possibly more than any other profession—has the power to change the way we interact with our world. True, engineers created the industrial systems that today are pumping billions of metric tons of pollutants into the air and water. But engineers are also capable of designing a new breed of products that reduce harmful emissions, reuse waste materials, and recycle resources. It is within the engineer's power to envision—and create—a new generation of buildings, vehicles, machines, devices, and services that deliver the functionality people want without destroying the ecosystem or depleting scarce resources.

If you're passionate about changing our cultural course and making a tangible, lasting impact, you're in the right place at the right time.

Core Challenges of Eco-Engineering

Eco responsibility remains difficult and uncharted territory for most engineers today, despite the unsustainable nature of today's products and services. Five particular challenges stand out.

- The number of possible environmental impacts is large, and each one can, in and of itself, be difficult to calculate.
- Key impacts of your product may lie outside your company. For
 example, there may be a large fresh-water impact at one of your suppliers as they make your product, or there may be significant GHG
 emissions at your customer site as they use your product.
- Most attempts to reduce impacts in one area result in impacts somewhere else. Using wind power is better than burning coal from a GHG point of view, but it involves the manufacture of wind turbines and visual impact to the natural landscape.
- Tradeoffs often involve things that appear, at the surface, to have little to do with each other. For example, what's the cost of cutting down and processing trees for paper bags, versus the short- and long-term waste issues of plastic bags? Many eco tradeoffs are similar, requiring us to make "apples versus oranges" comparisons.
- Engineers think they know how their products will be used, but customers use products how they want to, and transformative products often change users' behavior. Factoring this into product design can be tricky. Could Henry Ford have foreseen the scale of the behavioral change that resulted from widespread availability of affordable automobiles?

Moreover, very little formal training is focused on eco-engineering, despite the avalanche of press about "green" products and eco-friendly design. It is not part of the core curriculum in most engineering schools; it is not a common topic for on-the-job training courses; it's even hard to find a Webinar about eco-responsible engineering.

As a result, it is often difficult for engineers to get started. The next few chapters will help you understand how to work through these challenges and come up with an approach that works for your situation. And there are 7 billion reasons why we really need to get this right.