CHAPTER 4

Where We Work, Live, and Play: Technology for Highly Efficient Industry and Buildings

The energy used to power, heat, and cool our homes, businesses, and industries is the single largest contributor to global warming in the United States. Nearly three-quarters of all U.S. energy consumption—and two-thirds of all U.S. carbon emissions—come from those sectors. Fortunately, our industries and buildings are also where some of the most significant and readily available global warming solutions can be found. And no solution is more important to a comprehensive strategy for cutting emissions than energy efficiency.

Energy efficiency technologies allow us to use less energy to get the same—or higher—level of production, service, and comfort. We can still light a room, keep produce fresh, and use a high-speed computer, but we can do it with less energy. Energy efficiency is an appealing strategy because it can yield quick, significant, and sustained energy savings, which typically provide substantial long-term economic returns for consumers and businesses. But technology cannot do it alone. Creating a highly energy-efficient economy also requires policies and programs to help overcome significant, entrenched barriers, and to help businesses and consumers make wise decisions and find ways to eliminate wasteful and unnecessary uses of energy.

Our analysis relied on a supplemental analysis by the American Council for an Energy-Efficient Economy (ACEEE) of the costs and energy savings resulting from policies and programs aimed at spurring the use of energy-efficient technologies in the residential, commercial, and industrial sectors. We used the energy savings resulting from the ACEEE analysis to reduce electricity and fossil fuel use in UCS-NEMS. The model then determined the effects of the cuts in energy use on electricity generation, fossil fuel used to produce electricity, carbon dioxide emissions, energy prices, and energy bills resulting from those policies.[26]

This chapter explores some of the key energy-efficient technologies and innovations that will have the greatest effect in reducing heat-trapping emissions during the coming decades. The chapter then examines the potential for deploying these technologies on a large scale, their associated costs and savings, key challenges and barriers to reaching their full potential, and the suite of policies that the Blueprint supports to help drive their use.

4.1. Energy Efficiency Opportunities in Industry

The industrial sector is an essential component of the U.S. economy, producing millions of different products for consumers each year. That production currently uses a tremendous amount of energy. Industry is responsible for about one-third of all U.S. energy consumption—more than any other sector of the economy—and is also America's second-largest consumer of coal, primarily in the steel, chemicals, and pulp and paper industries. As a result, industry is responsible for more than one-quarter of total U.S. CO_2 emissions, including those from the electricity that industry uses (EIA 2009).

Industry is also a highly diverse sector, with processes, equipment, and energy demands across and within various arenas varying widely (Shipley and Elliot 2006). Petroleum refining, chemicals, and primary metals, for example, account for more than 60 percent

26 See Appendix C online for more information on the analysis by ACEEE.

Using an innovative design process, Atlanta-based carpet manufacturer Interface decreased its energy consumed per square yard of product by 45 percent. This achievement is part of a broader vision for sustainability that Interface founder Ray Anderson and his team have parlayed into a global leadership position in the carpet tile industry.

of all energy consumption in the industrial sector. Other industries—such as computers, electronics, appliances, and textiles—are far less energy intensive (EIA 2005). Many of the opportunities for boosting energy efficiency are therefore industry- and site-specific. Achieving our national goals for reducing emissions, then, requires identifying and capitalizing on both industry-wide and site-specific opportunities to deploy energy-efficient technologies and practices.

Numerous studies show an abundance of cost-effective energy efficiency solutions across all industries (Creyts et al. 2007; Nadel, Shipley, and Elliott 2004; IWG 2000). Some of the best opportunities include replacing existing equipment, pursuing innovations in more efficient processes and production technologies, using combined-heat-and-power systems, and relying on recycled petroleum feedstocks.

4.1.1. Equipment Replacement

The electric motor accounts for more than two-thirds of all industrial consumption of electricity (EIA 2008a). Investing in more efficient motors has historically provided significant gains in industrial efficiency—but many opportunities for upgrading today's equipment remain. Improving how companies maintain and coordinate their in-house motor systems can also save energy (Shipley and Elliott 2006). Retrofits to compressed-air systems, heating, ventilating, and air conditioning systems, furnaces, ovens, boilers, and lighting can provide further efficiency gains (Ehrhardt-Martinez and Laitner 2008).

4.1.2. Innovation in Industrial Processes

Some of the best options for boosting energy efficiency involve integrating new technologies into industrial processes. Advanced sensors, wireless networks, and computerized controls optimize energy use while also providing other benefits, such as higher productivity, greater quality assurance, and reduced waste of materials and other inputs (Ondrey 2004). Companies can also reap significant savings by redesigning entire processes to make them more efficient.

4.1.3. Combined-Heat-and-Power Systems

Combined heat and power (CHP) is a well-established but underused technology that entails generating electricity and heat from a single fuel source—dramatically increasing energy efficiency. By recovering and reusing the waste heat from producing electricity, CHP systems can achieve efficiencies of up to 80 percent, compared with about 33 percent for the average fossil-fueled power plant.

Continued advances in CHP and other thermal systems—such as even more effective recovery of waste heat, and the use of such systems for cooling and drying—stand to contribute significant energy savings and cuts in carbon emissions by 2030. Much of the remaining potential lies in industries that have traditionally used CHP, including pulp and paper, chemical, food, primary metals, and petroleum refining. However, industries such as textiles, rubber and plastics, and metal fabrication have considerable untapped potential for using smaller CHP systems (EIA 2008a; EIA 2000).

4.1.4. Recycled Petroleum Feedstocks

Sources of energy not only power industry but also serve as an ingredient—or feedstock—in manufacturing processes. The largest use of petroleum in the manufacturing sector, for example, is as a feedstock in the production of chemicals and plastics. Natural gas, meanwhile, is a key feedstock in the production of fertilizers. Improved techniques and processes that replace virgin petroleum with high-quality recycled or alternative feedstocks are poised to play an important role in reducing carbon emissions.

4.2. Energy Efficiency Opportunities in Residential and Commercial Buildings

The energy used in the buildings where we live, work, shop, meet, and play contributes significantly to our carbon emissions. The residential and commercial sectors account for 21 percent and 18 percent, respectively, of total U.S. energy use as well as CO_2 emissions, including emissions from electricity used in buildings (EIA 2009). Both sectors use energy primarily to heat and cool spaces, heat water, provide lighting, and run refrigerators and other appliances and electronics (see Figure 4.1). A wealth of readily available solutions for each use could reduce consumption and carbon emissions without sacrificing comfort or quality.

4.2.1. Heating and Cooling

Heating and cooling accounts for nearly half of the average energy consumed in homes—in the form of electricity, gas, and oil—and 43 percent of that used in commercial buildings. Leaks in the average building envelope mean that up to 30 percent of this energy is lost (EERE 2006).

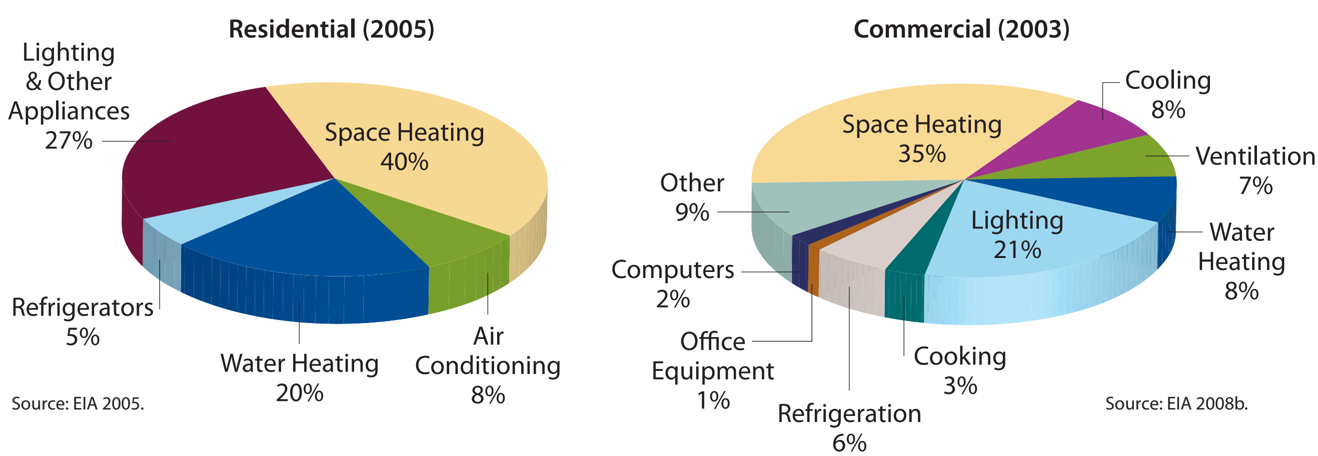
To keep more heat in during winter and more heat out during summer, existing and new structures can be outfitted with better and more appropriate insulation in walls, ceilings, and basements and around ductwork. Highly efficient windows with multiple panes, low-emissivity glass, and insulated frames can also reduce heating and cooling energy use by 20–30 percent (EERE 2006). Radiant barriers—a layer of reflective material in a roof that prevents heat transfer—can also moderate seasonal temperature exchanges in attic spaces, while lighter-colored rooftops can reduce unwanted solar heat gain in warmer climates.

Next to buttoning up a building's envelope, the use of highly efficient equipment can have the biggest impact on reducing carbon emissions from heating and cooling. Owners can easily install ultra-high-efficiency boilers, furnaces, and air conditioners already available in new buildings, or in existing structures when equipment wears out. Because most equipment is typically built to last 15 to 25 years, the most efficient models can provide significant long-term energy savings.

Simple, common-sense decisions often make a significant difference in the long run. Light-colored roofs, like this one at Atlanta's Energy and Environmental Resource Center, reflect sunlight, keeping buildings cooler, reducing demand for air conditioning, lowering electricity use, and saving money.

Most heating systems use natural gas, oil, or electricity as an energy source, but several existing and

FIGURE 4.1. Residential and Commercial Energy Use



Space heating and cooling account for the largest portion of home and business energy budgets. Lighting, water heating, and refrigeration are also substantial energy consumers in buildings. Fortunately, there are significant opportunities for energy and cost savings through efficiency.

emerging sources offer greater efficiency. For example, geothermal (ground-source) heat pumps use the constant temperature below ground to provide heating or cooling with much less energy. Air-source heat pumps, which use the difference between outdoor and indoor air temperatures for cooling and heating, are also effective in more moderate climates. Micro-combined-heat-and-power systems are also an emerging option that can allow commercial buildings and homes to get the most out of their fuel use. Similar to larger systems, micro-CHP meets heating and even cooling needs with the excess heat from on-site electricity generators powered, for instance, by natural gas.

Several other solutions from simple to high-tech can also help save energy and cut carbon emissions from heating and cooling. Ceiling fans can significantly reduce the need for air conditioning, and programmable thermostats (which can even be controlled remotely) can reduce energy use by 5–15 percent. Passive solar designs can minimize energy use and increase the comfort of new buildings by considering the sun's location at various times of year. For example, large south-facing windows with good overhangs can let winter sun in and keep summer sun out. Well-placed trees can also help shade buildings from the high summer sun and protect them from winter winds.

Energy efficiency in buildings generates many types of jobs—for contractors, plumbers, and electricians who renovate existing buildings as well as engineers and architects who design new ones. Some architects specialize in passive solar design that decreases a building's lighting and heating needs.

4.2.2. Water Heating

Water heating offers strong opportunities for cutting carbon emissions, as it accounts for about 20 percent of energy used in residential buildings, and 8 percent of energy used in commercial buildings (EIA 2008b; EIA 2005). High-efficiency water heaters that are available today use 10–50 percent less energy than standard models, and new advances are expected to offer further gains (EPA 2008b).

On-demand or "tankless" water heaters, which heat water only when it is needed, reduce energy consumption 10–15 percent by avoiding "standby" losses (Amann, Wilson, and Ackerly 2007). Innovations in gas-condensing water heaters—which capture and use warm combustion gases to heat water further, before releasing the gases to the outdoors—can reduce the amount of energy used to heat water by as much as 30 percent (EPA 2008b).

Fuel choice is also important for curbing carbon emissions. Natural-gas-fired water heaters are far more efficient than those powered by oil or electricity, if we account for the inefficiencies that occur producing the electricity. However, solar water heaters offer the greatest cuts in carbon emissions. Innovations in the design of such systems have improved their efficiency, significantly reduced their cost, and allowed their use in most climates.

4.2.3. Lighting

Lighting accounts for about 10 percent of an average home's energy use, and more than 20 percent of the energy used in the commercial sector (EIA 2008b; Amann, Wilson, and Ackerly 2007). Large-scale changes to the lighting industry now under way will deliver significant cuts in energy use and carbon emissions.

A provision in the Energy Independence and Security Act of 2007 (EISA) requires lightbulbs to be 30 percent more energy efficient starting in 2012, with further reductions mandated by 2020. These new standards will effectively phase out traditional incandescent bulbs.[27] Their replacements will be compact fluorescent

27 Our Reference case included the lighting efficiency standard and other provisions in EISA.

lightbulbs (CFLs), light-emitting diodes (LEDs), and advanced incandescent lamps that use halogen capsules with infrared reflective coatings now in development. EISA's provision for efficient lightbulbs is projected to reduce annual U.S. carbon emissions 28.5 million metric tons by 2030 (ACEEE 2007).

Gas discharge lamps—such as metal halide and sodium vapor—which pass electricity through gases to produce light, are two to three times more efficient than CFLs, and thus save even more energy. These lamps are typically used in office buildings and retail outlets because of their large size. However, technological advances are broadening their application to smaller-scale residential uses.

Of course, lighting uses the least amount of energy when it is turned off. Building designs that maximize natural light from the sun (known as daylighting) through the use of windows, skylights, and glass partitions can significantly reduce energy use in both residential and commercial settings. Sensors that adjust lamp output based on ambient lighting conditions, and automatically turn off lights in empty rooms, can also help cut global warming emissions.

4.2.4. Appliances and Electronics

Large appliances such as refrigerators, washing machines, and dishwashers account for about 20 percent of household energy use. Electronics comprise a smaller but growing share of electricity demand—primarily because of the rapid growth of larger television screens, faster computers, video games, and handheld devices such as cell phones and MP3 players.[28] Manufacturers have made great strides in enabling many of these products to run on less power. For example, innovations in motors, compressors, and heat exchangers, as well as better insulation, have made today's refrigerators three times more efficient than their 1970s counterparts (Nadel et al. 2006).

High-efficiency models of most appliances and electronics are available today. The models highlighted by the U.S. Environmental Protection Agency's Energy Star program typically offer energy savings of 20 percent or more. Electronics manufacturers are also continuing to research and design equipment, appliances, and gadgets that are more energy efficient. These rely on ever-smaller microprocessors for computers, organic LEDs (which use a thin film made from organic compounds) for lighting large-screen TVs, and microhydrogen fuel cells to replace lithium-ion batteries.

Standards designed to increase the energy efficiency of home appliances and electronics help consumers save money on electricity bills by reducing energy demand. For example, America's 275 million televisions consume more than 50 billion kilowatt-hours of electricity each year—equivalent to the output of more than 10 coal-fired power plants. Efficient Energy Star televisions use 30 percent less power.

4.2.5. On-Site Generation of Clean Electricity

Homes and businesses can also reduce carbon emissions by using clean and renewable resources to generate electricity on-site. Solar electric systems (known as photovoltaics, or PV) are an option for any building with good access to the sun. Advances in technology are also opening up new opportunities to integrate PV into buildings directly—in place of shingles, façades, skylights, or windows. Small-scale wind systems may also be an effective option for generating carbon-free electricity on-site, particularly in rural areas.[29]

Potential

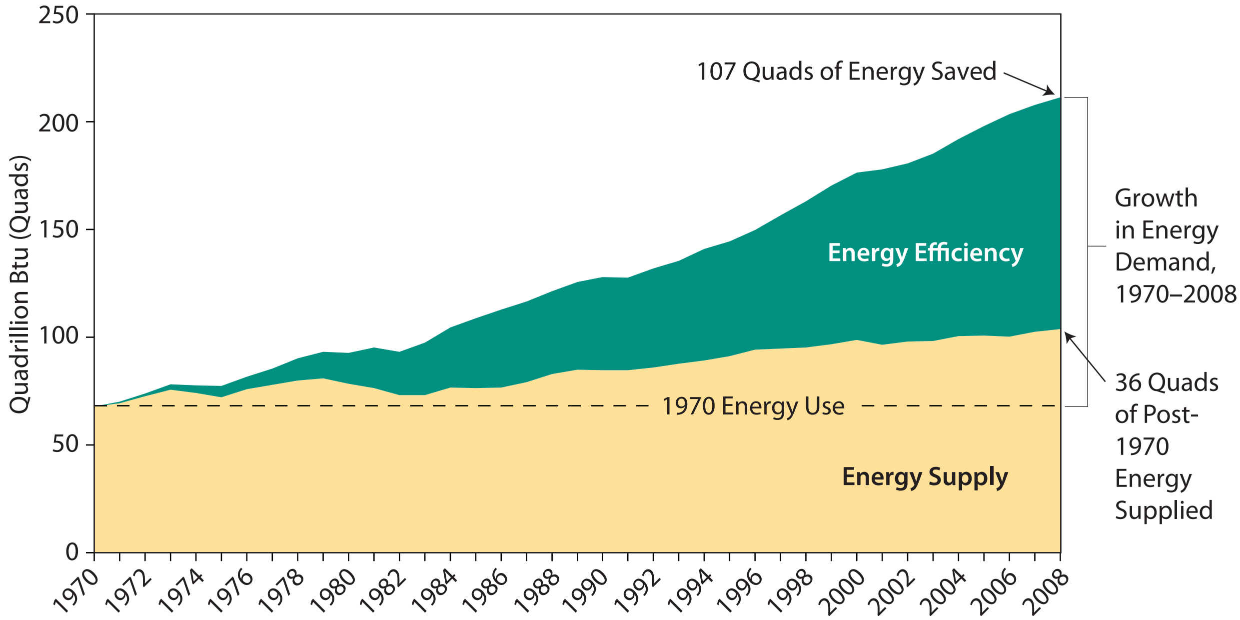
4.3. Potential for Greater Efficiency

Energy efficiency has already been working hard and providing significant dividends to the U.S. economy for nearly four decades. A recent study found that energy-efficient technologies and practices have actually met *three-quarters* of all new demand for energy services since 1970 (see Figure 4.2). Over that same period, the energy intensity of the U.S. economy—that

28 The appreciable amount of energy used by many household electronics when not in operation is another opportunity. These standby energy losses—also known as "vampire" or "phantom" losses—add up to some 65 billion kilowatt-hours of electricity per year, or about 5 percent of residential electricity use. See *www.ucsusa.org/publications/greentips/energy-vampires.html.*

29 Chapter 5 and Appendix D (available online) describe renewable energy technologies in greater detail.

FIGURE 4.2. Efficiency Helps Meet U.S. Energy Demand



Source: Ehrhardt-Martinez and Laitner 2008.

Over the past four decades, U.S. energy needs have more than tripled. Energy-efficient technologies and practices have been able to meet three-quarters of this demand, sharply reducing the amount of conventional energy resources needed to meet remaining demand. Further advances in energy efficiency have the potential to make even greater cuts in energy use across all economic sectors and within every region of the country.

is, energy consumption per dollar of economic input—has fallen by more than half, largely because of improved efficiency (Ehrhardt-Martinez and Laitner 2008). Yet despite these important successes, energy efficiency is an underused resource in the United States. A massive reservoir of potential energy efficiency remains untapped, ready to contribute to the challenge of reducing our carbon emissions.

Research into the potential of energy efficiency typically considers only measures that are or may become cost-effective, rather than the full—or "technical"—potential. A recent meta-analysis of 11 studies at the state and national level found that the technical potential for reducing energy use from efficiency measures is 18–36 percent for electricity, and 38–47 percent for natural gas (see Table 4.1) (Nadel, Shipley, and Elliot 2004).

The greatest potential for reducing the use of electricity through energy efficiency lies in the commercial and residential sectors. For natural gas, the potential for energy efficiency is greatest in the residential sector, specifically in space and water heating.

The nation also has a wealth of untapped potential for using new combined-heat-and-power systems to boost energy efficiency. The industrial sector has installed about 26,000 megawatts of CHP capacity, which now supply about 7.5 percent of all U.S. electricity use. This capacity is dominated by large systems—those that produce more than 20 megawatts—in the pulp and paper, chemical, food, primary metals, and petroleum refining industries (EIA 2008a).

The total technical potential of CHP at industrial facilities today is estimated at 132,000 megawatts (EIA 2000). The commercial sector—including hospitals, schools, universities, hotels, and large office buildings—

TABLE 4.1. Energy Efficiency Potential
(percent reduction in energy use)

Sector	Natural Gas	Electricity
Residential	46–69%	22–40%
Commercial	16–29%	17–46%
Industrial	NA	18–35%
Total, All Sectors	**38–47%**	**18–36%**

Source: Nadel, Shipley, and Elliot 2004.

Note: These reductions represent technical potential. Real-world barriers may prevent these sectors from reaching their full potential.

also has tremendous opportunities to deploy CHP systems. The total technical potential of CHP in this sector is some 77,000 megawatts (EIA 2000).

Costs

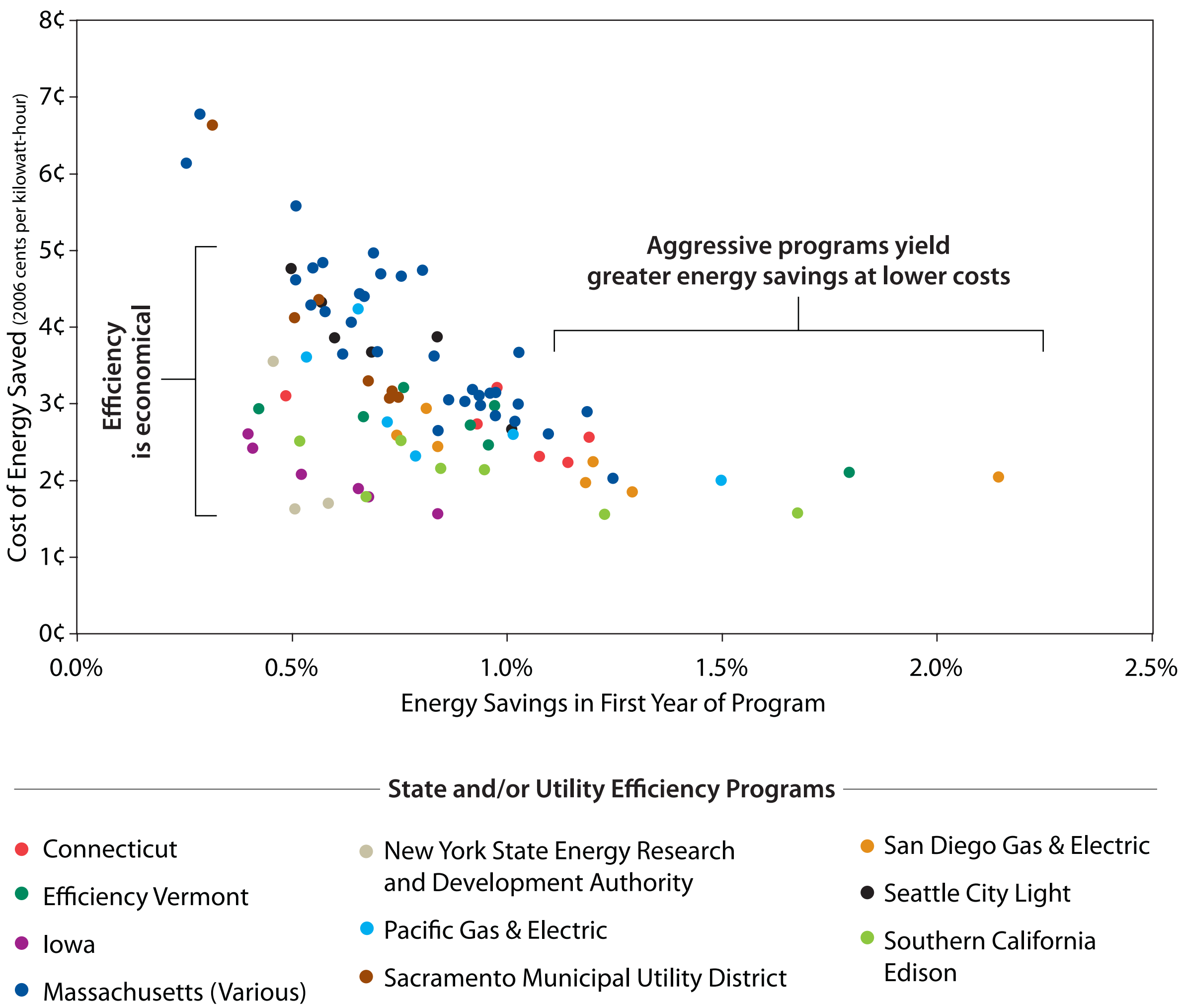
4.4. Costs of Improving Energy Efficiency

Understanding the technical potential of energy efficiency can offer an upper bound on the role it can play in helping to reduce global warming emissions. However, the solutions that prove the most economical are the most likely to be developed. Technologies and practices that improve energy efficiency tend to be more cost-effective than other global warming solutions—which is why efficiency must be the cornerstone of any comprehensive strategy for cutting carbon emissions.

Over time, reductions in energy use more than offset the initial costs of most efficiency solutions—so they often provide significant long-term economic benefits. By reinvesting some of the money saved on energy bills, the nation can afford to invest in other critical global warming solutions that may be more expensive.

For example, a 2007 analysis by McKinsey & Company found that measures and technologies that

FIGURE 4.3. The Energy Savings and Costs of Efficiency Programs



Source: Adapted from Hurley et al. 2008.

A review of utility- and state-level efficiency programs found that the cost of implementing energy efficiency measures ranged from about 1.5 cents to nearly 7 cents per kilowatt-hour (¢/kWh) saved, with a median of 3.0 ¢/kWh. This is lower than the average U.S. retail price for electricity (about 9.1 ¢/kWh). The review also found that implementation costs are cheaper when a program enables greater efficiency gains. This suggests that an aggressive, comprehensive plan to boost energy efficiency nationwide—as recommended in the Blueprint—is the most cost-effective approach and would provide the greatest benefits for consumers.

BOX 4.1.

SUCCESS STORY

The Two-Fer: How Midwesterners Are Saving Money while Cutting Carbon Emissions

In every region of the country, people are seeing the advantages of improving energy efficiency in residential buildings. Single-family homes, apartment buildings, and even entire neighborhoods can be built new or renovated to boost energy efficiency—saving families money while reducing heat-trapping emissions.

Cleveland may, at first blush, seem an unlikely place to find green homes. The post-industrial city suffers from severe winters, residential flight, and industrial decline. By adding Cleveland to the emerging midwestern "Green Belt"—a reference to the region's moniker as the Rust Belt—the city's residents, businesses, and government see an opportunity to attract new industries and reverse population decline.

Artfully mixed with historic housing, the new energy-efficient homes in Cleveland's EcoVillage add to the diversity of Detroit-Shoreway—a neighborhood of mostly renting families, with a few young professionals and "empty nesters." Believing that a stable neighborhood is a socioeconomically mixed one (Hansen 2008), EcoVillage designers worked with the community to integrate these new homes into the fabric of the neighborhood (Metcalf 2008).

The 20 new village townhouses and two single-family homes sold for close to median market prices. Five "green" cottages will be made available to residents making less than 80 percent of Cleveland's median income (Dawson 2008). All the homes are equipped with energy-efficient appliances, double-pane windows, extra insulation, and high-performance heating, cooling, and air conditioning systems, to reduce energy use and utility bills.

Some units take advantage of passive solar heating through south-facing windows, and were built with framing that leaves space for more insulation (Metcalf 2008). Four of the townhouses also have photovoltaic panels on their garages, supplying a substantial percentage of each home's electricity needs. Reports Mandy Metcalf, former EcoVillage project director, "A couple of the homeowners that have the panels were getting negative energy bills, actually getting credits on their energy bills" (Metcalf 2008).

Thanks to these simple construction techniques and the use of energy-efficient products—which are available around the country for competitive prices—heating bills for residents of EcoVillage are drastically lower than those for residents of standard housing. For example, heating costs for one of the three-bedroom green cottages are projected to be only $432 per year—less than half the amount a typical midwestern household expected to spend during the 2008–2009 winter (Cuyahoga Land Trust 2008; EIA 2008c).[30]

Ohio's EcoVillage cottages (left) and Minnesota's Viking Terrace apartments (right) are good examples of how energy efficiency and smart building design can save money and reduce carbon emissions all around the country.

The renovation of Viking Terrace, an income-based rental complex in rural Minnesota, is another green housing success story. With funding from the city and federal governments, nonprofit organizations, and low-income housing tax credits, the Southwest Minnesota Housing Partnership renovated 60 dilapidated apartments into energy-efficient, clean, safe, and affordable housing. The apartments are now equipped with Energy Star appliances and windows, improved insulation, water-conserving appliances and fixtures, a new ventilation system, and a metal gable roof (Minnesota Green Communities n.d.).[31] Renovators also installed a high-efficiency geothermal heating and cooling system—the project manager's proudest, and largest, investment (Lopez 2008). The partnership expects this system to pay for itself through energy savings in just a decade, and tenants say they love it (Lobel 2007).

With these installations, the partnership expects to cut household energy and water use by 40 percent (Buntjer 2007)—a significant decrease in the harsh Minnesota climate. Today all 60 apartments are happily occupied, and 15 families are on the waiting list. Four of the apartments are affordable to families earning 30 percent of the area's median income, while 47 are affordable to families earning 50 percent of the median (Minnesota Green Communities n.d.)—a strong testament to the desirability and economic benefits of green renovations.

30 The Energy Information Administration projected that the average midwestern household would spend $1,056–$1,175 on heat during the winter of 2008–2009. That range reflects the different prices of heating fuels. The cost of heating with electricity was expected to be $1,056, while the cost of heating with propane was projected to be $1,941. The cost of heating with natural gas and oil fell within this range (EIA 2008c).

31 Pumping, distributing, treating, and heating water takes energy. Running a standard hot water faucet for five minutes requires about as much energy as keeping a 60-watt lightbulb lit for 14 hours (City of Chicago 2008), and water heating alone accounts for 13–17 percent of a typical household's utility bill (EERE 2009a).

By reflecting light and heat back into the air rather than absorbing and transferring it to the house below, as traditional black roofs do, metal roofs can substantially reduce the energy required to cool houses. According to the Energy Star program, qualified reflective roofing can lower surface temperatures by up to 100°F, and reduce peak cooling demand by 10–15 percent (Energy Star 2009).

provide positive economic returns could provide nearly 40 percent of the cuts in carbon emissions required by its mid-range case. Of these cost-effective solutions, nearly 60 percent stem directly from energy efficiency gains in industry and buildings. McKinsey's mid-range case projects that making buildings and industry more efficient could reduce U.S. demand for electricity 24 percent by 2030. That, in turn, could provide one-third of the needed reductions in CO_2 emissions, at an average weighted net savings of $42 per ton of CO_2 equivalent (in 2005 dollars) (Creyts et al. 2007).

Our analysis of policies to promote energy efficiency shows that they can reduce total U.S. energy consumption 29 percent (12 quadrillion Btu, or 12 quads) by 2030—or an average of 1.3 percent per year. We assumed that the annual costs of those policies would reach $7.5 billion in 2020, and rise to $13.4 billion in 2030. Those costs include expenditures related to developing and administering programs, research and development, and incentives to encourage households and businesses to boost energy efficiency. Those expenditures, in turn, stimulate $64.3 billion in new spending for more energy-efficient technologies and measures in 2020, and $113.6 billion in 2030. (See Table 4.3 for a breakdown of policy and investment costs.) The levelized cost of these investments in energy efficiency would be about $12.62 per million Btu.[32]

Other recent studies also suggest that energy efficiency could cost-effectively reduce U.S. energy use 25–30 percent over the next 20 to 25 years, or 1–1.5 percent per year (Ehrhardt-Martinez and Laitner 2008; ASES 2007; Nadel, Shipley, and Elliott 2004; IWG 2000).

Leading state energy efficiency programs have already achieved such annual cuts in energy use. For example, energy efficiency programs in Vermont reduced electricity use by more than 1.7 percent in 2007, and have averaged cuts of more than 1.1 percent since 2003 (Efficiency Vermont 2007). California has also seen aggressive reductions: per capita electricity use has remained constant in that state since the mid-1970s, while rising nearly 50 percent in the country as a whole (CEC 2007).[33] During California's energy crisis in 2001, about one-third of the 6 percent drop in electricity use came from

32 The levelized cost is the annualized cost of the total efficiency investment divided by the total savings.

33 While California's steady per capita electricity use likely stems from a range of factors, its early energy efficiency policies were a major factor in enabling the state to meet growth in energy demand with greater efficiency (Sudarshan and Sweeney 2008).

investments in energy-efficient technologies (Global Energy Partners 2003).[34]

Reducing energy use a minimum of 1 percent per year is consistent with key commitments by leading states. California, Connecticut, and Michigan all require annual savings in electricity use of 1 percent. Other states and regions have adopted even higher requirements, including Minnesota (1.5 percent), Maryland (~2 percent), Illinois (2 percent starting in 2015), Ohio (2 percent starting in 2019), and the Midwestern Greenhouse Gas Reduction Accord (2 percent).[35]

A recent review of 14 utilities, groups of utilities, and state efficiency programs found that the cost of measures for making electricity use more efficient ranged from about 1.5 cents to nearly seven cents per kilowatt-hour saved, with a median of three cents per kilowatt-hour (Hurley et al. 2008). That analysis also uncovered a correlation between the cost of reducing energy use and the size of the program. That is, energy savings are cheaper when a program itself achieves greater efficiency (Hurley et al. 2008).

Energy use in existing buildings represents a significant portion of residential and commercial electricity demand. Because most buildings standing today will still exist in 2030, energy-saving improvements such as additional insulation or replacement windows will be necessary to reduce the carbon emissions associated with these buildings.

This finding suggests that an aggressive, comprehensive plan to boost energy efficiency nationwide could benefit from economies of scale as well as more effective coordination (Hurley et al. 2008). Indeed, while cuts in energy use from some mature efficiency technologies might decline with more widespread use, our analysis assumes that any diminishing returns would be more than offset by economies of scale and the introduction and growth of newer technologies.

Challenges

4.5. Key Challenges for Improving Energy Efficiency

Despite clear economic and environmental advantages, energy efficiency still faces many market, financial, and regulatory barriers to achieving its full potential. One of the steepest market barriers is the "split incentive" (Prindle et al. 2007). That is, builders of new homes and businesses have a strong motivation to keep construction costs low, and little incentive to optimize a building's efficiency, as buyers will be the ones paying for energy use. Landlords are similarly less interested in investing in energy efficiency when tenants reap most of the benefits (Ehrhardt-Martinez and Laitner 2008).

Lack of information among energy consumers is another common challenge. They may not be aware of, or simply underestimate, the impact of the efficiency of their purchases—whether a handheld gadget, major appliance, or even a house—on energy use. Such information is often not readily available, and consumers may not have the time, ability, or inclination to do the required research. And at companies and large institutions, maintenance staff or other employees who lack complete information—or who place a higher priority on keeping capital costs low than on overall costs—often make purchasing decisions (Nadel et al. 2006).

Higher-efficiency products also typically have higher up-front costs than their counterparts. Homeowners and businesses may lack the capital or financing to make larger initial investments. And publicly traded corporations focused on showing profits to shareholders are often unwilling to make investments in energy efficiency that do not produce significant near-term returns.

Particular technologies or approaches to energy efficiency face additional barriers. Despite the clear

34 The remainder resulted from aggressive conservation measures.

35 The Midwestern Greenhouse Gas Reduction Accord is a regional agreement by governors of six states (Illinois, Iowa, Kansas, Michigan, Minnesota, and Wisconsin) and the premier of Manitoba to reduce emissions to combat climate change. For more information, see Box 3.2.

TABLE 4.2. **Energy Savings in Buildings and Industry from Blueprint Policies**

Blueprint Policies	Electricity Savings (billion kilowatt-hours)		Total Energy Savings[a] (quadrillion Btu)	
	2020	2030	2020	2030
Appliance and Equipment Standards	104	193	1.01	1.75
Energy Efficiency Resource Standard	390	652	2.17	3.68
Energy Efficiency Codes for Buildings	131	223	0.76	1.25
Advanced-Buildings Program	69	168	0.46	1.06
R&D on Energy Efficiency	18	200	0.17	1.76
Combined-Heat-and-Power Systems[b]	264	453	0.34	0.58
Energy-Efficient Industrial Processes	51	100	0.89	1.73
Enhanced Rural Energy Efficiency	3	3	0.01	0.01
Use of Recycled Petroleum Feedstocks	—	—	0.16	0.26
Total	**1,030**	**1,992**	**5.97**	**12.08**

Notes:

a Total energy savings include reductions in the use of electricity as well as natural gas, home heating oil, and other sources of energy.

b Total energy savings for combined heat and power include more widespread use of natural gas in the commercial and industrial sectors, equal to 0.56 quadrillion Btu.

The suite of Blueprint efficiency and combined-heat-and-power policies deliver strong energy savings by 2020, and by 2030, the efficiency gains double in size.

economic advantages of CHP, for example, significant regulatory and market barriers that discourage power producers other than utilities are preventing it from achieving its full potential. For example, developers of CHP projects seeking to connect with the electricity grid often face discriminatory pricing and technical hurdles by uncooperative utilities (see Brooks, Elswick, and Elliott 2006). High-quality recycled materials that could replace petroleum feedstocks in industry also face market barriers, such as lack of knowledge among manufacturers of how to process those resources.

Cutting carbon emissions swiftly and deeply, meanwhile, will require making existing buildings more energy efficient. New technologies and advanced building designs are usually easier to introduce into new construction. Yet more than 113 million single-family, multi-family, and mobile homes already exist, and commercial buildings have more than 75 billion square feet of floor space (EIA 2009). The vast majority of these buildings will still be in use in 2030, and most will still be standing even in 2050. The nation will need to mount a concerted and coordinated effort—supported by effective public policies—to improve the energy efficiency of these structures.

Policies

4.6. Key Policies for Improving Energy Efficiency

As part of its analysis, the American Council for an Energy-Efficient Economy evaluated the costs and energy reductions of a suite of policies designed to remove key obstacles to maximizing the impact of energy efficiency (see Table 4.2). These policies build on the most effective approaches by leading states and the federal government.

4.6.1. Energy Efficiency Standards for Appliances and Equipment

Appliance and equipment standards save energy by requiring that various new products achieve minimum levels of efficiency by a certain date. As higher-efficiency products gradually enter the market, they replace older, less-efficient models while still offering consumers a full range of options. Such standards help overcome market barriers to more efficient products, such as lack of awareness among consumers, split incentives between developers and buyers (and landlords and tenants) and limited availability of such products.

Efficiency standards have been one of the federal government's most successful strategies for reducing

The new "whole-building" approach to architecture attempts to incorporate energy efficiency and passive solar technologies while creating an attractive, open aesthetic. One impressive example in Michigan, the Grand Rapids Art Museum (shown here both inside and out), meets the gold standard of sustainability criteria established by the U.S. Green Building Council and was named one of *Newsweek*'s Six Most Important Buildings of 2007.

energy consumption in homes and businesses since their inception in 1987. For example, the annual amount of energy saved primarily due to efficiency standards for appliances and equipment reached 1.2 quadrillion Btu (1.3 percent of total energy use) in 2000. By 2020, annual energy savings from today's efficiency standards are projected to grow to 4.9 quads (4.0 percent)—equivalent to the total energy used by some 27 million homes (Nadel et al. 2006).

The Blueprint assumes that the federal government establishes new or upgraded efficiency standards for 15 types of appliances and equipment—including incandescent lamps, electric motors, refrigerators, and clothes washers—over the next several years.

4.6.2. Energy Efficiency Resource Standard

The energy efficiency resource standard (EERS) is emerging as an effective way to promote investment in energy-efficient technologies. Similar to a renewable electricity standard, an EERS is a market-based policy that requires utilities to meet specific annual targets for reducing the use of electricity and natural gas (Nadel 2006). Besides spurring significant cuts in the use of both electricity and natural gas, an EERS can reduce excess demands on the capacity of the grid used to transmit electricity. Some 18 states as well as countries such as France, Italy, and the United Kingdom have adopted such a standard.

The Blueprint assumes that the federal government sets an EERS that applies to the use of both electricity and natural gas. The electricity target would reduce demand for power by 0.25–1 percent each year, to achieve a total reduction of 10 percent by 2020 and 20 percent by 2030. The natural gas target would eventually reach 0.5 percent annually, reducing use of that energy source a total of 5 percent by 2020 and 10 percent by 2030.[36] Those targets are consistent with standards in leading states such as Minnesota and Illinois, which sometimes set even stricter targets (Nadel 2007).

4.6.3. Energy Efficiency Codes for Buildings

Energy codes for buildings require that all new residential and commercial construction meets minimum criteria for energy efficiency. Adopting more stringent energy codes over time ensures that builders deploy the most cost-effective technologies and best practices in all new construction.

The Blueprint assumes that efficiency codes reduce energy use 15 percent in new residential and commercial construction through 2020, and 20 percent from 2020 to 2030. Those cuts in energy use modestly improve on today's building codes, and are well within

36 The EERS does not include any contributions from combined-heat-and-power systems or recycled petroleum feedstocks. This chapter addresses those contributions separately.

the goals recently established by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), and DOE.

4.6.4. Advanced-Buildings Program

New homes and businesses can save even more energy beyond the cuts prompted by enhanced building codes, if architects design new structures directly for energy efficiency. An advanced-buildings program combines training and technical assistance on new design and construction techniques for architects, engineers, and builders with educational outreach to purchasers on the benefits of energy efficiency. National efforts such as the Environmental Protection Agency's Energy Star program, the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program, and the New Building Institute's Core Performance program encourage builders to incorporate sustainable practices into their construction and help educate consumers.

The Blueprint assumes that a targeted advanced-buildings program gradually ramps up to achieve a 15 percent reduction in energy use by new residential and commercial buildings by 2023, with savings continuing at that level through 2030. This potential is consistent with those considered in other analyses (Elliott et al. 2007a; Sachs et al. 2004).

4.6.5. R&D on Energy Efficiency

Existing knowledge of energy efficiency can lead us far down the path to critical cuts in carbon emissions. However, the scale of the global warming crisis requires us to develop new technologies and practices over the coming decades. Investment in research and development is therefore essential to identifying and commercializing these approaches.

Federal R&D programs have a long history of advancing the performance and lowering the cost of emerging energy-efficient technologies. These programs are also a sound investment of taxpayer dollars, given that the lifetime economic benefits of such technologies typically far exceed their initial cost.[37]

The Blueprint bases cuts in energy use stemming from federal R&D programs on a study of potential reductions in Florida by ACEEE (Elliott et al. 2007b). We scaled up those savings to the national level, and assumed that a concerted national effort could double them. As a result of that investment, U.S. energy use falls 4.4 percent by 2030—accounting for about 15 percent of all reductions in energy use from greater efficiency, including CHP.

We also assumed that the nation would need to spend $80 million on R&D (in 2005 dollars over a five-year period) to develop a technology that eventually saves 1 million Btu of energy when it first enters the market, based on estimates from a 1997 report by the President's Committee of Advisors on Science and Technology (PCAST 1997). As a result, the Blueprint projects that a federal R&D program would cost nearly $1.8 billion annually in 2020, and more than $4.6 billion annually in 2030. This funding spurs $2.0 billion in private-sector investments in 2020, growing to $18.5 billion in 2030.

4.6.6. Combined-Heat-and-Power Systems

The nation will have to take several steps to reduce the barriers to widespread adoption of CHP. These include establishing:

- Consistent national standards for permitting and connecting CHP systems to the local power grid.

Combined-heat-and-power (CHP) systems are an energy-saving option for every region of the country. In Texas, CHP accounted for more than 21 percent of electric power generation in 2005, and more than 1,500 miles away, the small community of Epping, NH, installed the micro-CHP system shown here in its 125-year-old town hall. This system, integrated with an array of solar panels, has reduced the building's electric bill by 50 percent, its heating costs by 50 to 60 percent, and its carbon emissions by 60 tons per year.

37 See, for example, PCAST 1997.

BOX 4.2.

SUCCESS STORY

Three Companies Find Efficiency a Profitable Business Strategy

Regardless of size, location, or product, all companies agree: reducing global warming emissions must be a profitable business strategy. Here is how three companies accomplished that task.

DuPont

Inspired by scientific consensus on the urgency and magnitude of the threat from global warming, chemical manufacturing company DuPont cut its worldwide heat-trapping emissions 72 percent below 1990 levels in just 10 years (Hoffman 2006). The company achieved those drastic reductions first by capturing and destroying its most abundant global warming emissions (DuPont 2008).

The company then turned its attention to making its industrial processes and instrumentation more efficient, and to installing combined-heat-and-power systems (CHP) at a number of sites (Hoffman 2006). These energy-saving techniques paid off: DuPont's energy use fell 7 percent from 1990 to 2006, even while production expanded 30 percent, saving the company $2 billion (Hoffman 2006).

SC Johnson and Son

As a charter member of the EPA's Climate Leader's Initiative, SC Johnson and Son set an initial goal of reducing its domestic global warming emissions by 8 percent. Far surpassing that goal, the company achieved a 17 percent reduction (EPA 2009), and has committed to an additional 8 percent reduction by 2011 (SC Johnson & Son 2008).

The company credits its success to changes in the way it obtains its energy. Starting in Racine, WI, with its largest manufacturing facility—and largest carbon emitter—the company now uses landfill methane and natural gas to power a CHP plant that provides all of the facility's electricity, and more than half of the steam needed for its processes (EPA 2009). Saving the company millions of dollars annually on energy bills, the CHP plant will pay for itself in less than seven years (EPA 2009). The plant has also reduced the facility's global warming emissions by 52,000 tons per year (CSR 2007).[38]

Harbec Plastics

Near the shores of Lake Ontario in upstate New York, Harbec Plastics, a small local company, is using a similar business strategy to achieve the same success. Facing rising energy costs and frequent power outages, president and CEO Bob Bechtold decided to invest in new systems that would reduce his company's dependence on an unreliable electricity grid while cutting carbon emissions.

Bechtold first replaced the equipment at the core of his business with newer, more efficient machines. To provide reliable power for this equipment, Bechtold next installed a CHP system that more than handles the plant's electricity demand, and supplies heat and air conditioning at no extra cost (Bechtold 2008a). Both the energy-efficient machines and the CHP system required an up-front investment that the company recouped in two to three years through substantially lower energy bills (Bechtold 2008a).

Finally, Bechtold erected a wind turbine on-site to harness the steady wind blowing off the lake. Producing 10 percent of the plant's total electricity needs, the turbine saves the company $40,000 a year, and allows Bechtold to forecast a substantial portion of his energy bill far into the future (Bechtold 2008a).

These efforts have reduced Harbec's global warming emissions by more than 3,077 tons per year, and put the company on track to be carbon-neutral by 2016 (Bechtold 2008b). The cuts in energy use have also improved the company's bottom line: Harbec Plastics has exceeded its profit projections for the past three years despite failing to meet its sales projections (Bechtold 2008b).

These success stories show that up-front investments in energy-saving and energy-producing technologies not only provide significant cost benefits but also reduce heat-trapping emissions. Harbec Plastics, SC Johnson and Son, and DuPont are but three examples

38 This is equivalent to taking 7,700 cars off the road, calculated using an average of 6.75 tons of CO_2 emitted per car per year.

Bob Bechtold's use of microturbines within a combined-heat-and-power system is one of several energy innovations helping Harbec Plastics run efficiently and profitably.

of the many companies that have found cutting such emissions compatible with a sound and profitable business strategy.

Regardless of size, location, or product, all companies agree: reducing global warming emissions must be a profitable business strategy.

- Equitable interconnection fees, and tariffs for stand-by, supplemental, and buy-back power, to help overcome discriminatory pricing practices.
- Uniform tax treatment to level the playing field for all CHP systems regardless of their size or use, and to help reduce their initial capital costs.

The Blueprint also includes annual spending on federal and state CHP programs, such as the successful DOE/EPA CHP Regional Application Centers, which spur the use of CHP through education, coordination, and direct project support, such as site assessments and feasibility studies (Brooks, Elswick, and Elliott 2006). Under the Blueprint, the annual, amortized cost of such programs reaches $48 million in 2020, and $59 million in 2030.

The Blueprint assumes that these policies and investments produce 88,000 megawatts of new CHP capacity by 2030—or an average of 4,000 megawatts each year—representing nearly half of that technology's technical potential. This rate is consistent with increases this decade in states with effective CHP policies, such as Texas. In that state, CHP accounted for more than 21 percent of electric power generation in 2005—a 29 percent increase over 1999 levels (Elliott et al. 2007a).

4.6.7. Energy-Efficient Industrial Processes

Every aspect of the industrial sector has significant potential for low-cost improvements in energy efficiency. The key is to optimize the efficiency of the processes used in each industry and at each site (Shipley and Elliott 2006).

Programs that help facilities identify such opportunities and develop strategies for implementing them—such as the DOE's Industrial Assessment Centers and its Save Energy Now program—can enable industry to fulfill this potential. The Blueprint assumes that these and similar efforts will expand, and that local programs will support plant-level efforts.

These programs lead to a 10 percent reduction in the amount of fuel used in industry (not otherwise affected by the energy efficiency resource standard or CHP policies) by 2030. This target is consistent with the cost-effective cuts identified by the DOE, after evaluating more than 13,000 in-plant assessments conducted since 1980 (Shipley and Elliott 2006).

4.6.8. Enhanced Rural Energy Efficiency

Robust programs to improve the efficiency of energy use in agriculture emerged in the 1970s, in response to rising energy costs on this energy-intensive sector of

TABLE 4.3. **Key Policies for Improving the Energy Efficiency of Industry and Buildings**

	Total Savings in 2030 (in End-Use Quads)	Total Cost in 2030 (in Billions of 2006 Dollars)	
		Program	Investment
Appliance and equipment standards: The federal government upgrades energy efficiency standards or establishes new ones for 15 types of appliances and equipment over the next several years.	1.8	0.50	11.45
Energy efficiency resource standard (EERS): Federal standards rise steadily to 20 percent for electricity and 10 percent for natural gas by 2030.	3.7	1.63	16.26
Building energy codes: New codes cut energy use in new residential and commercial buildings 15 percent annually until 2020, and 20 percent annually from 2021 to 2030.	1.2	2.12	14.19
Advanced buildings: An aggressive program ramps up and results in an additional 15 percent drop in energy use in new residential and commercial buildings by 2023 (beyond minimum building codes), with savings continuing at that level through 2030.	1.1	3.96	21.78
Research and development: Annual R&D investments reach $4.6 billion in 2030, and stimulate additional private-sector investments that reach $18.5 billion that year. These investments result in a 4.4 percent reduction in U.S. energy use by 2030.	1.8	4.65	18.50
Combined heat and power (CHP): A range of barrier-removing policies and annual investments in federal and state CHP programs lead to about 88,000 megawatts of new capacity by 2030—an average annual addition of 4,000 megawatts.	0.6	0.06	27.57
Industrial energy efficiency: Expanded federal programs, combined with local programs that support plant-level efforts, reduce industrial fuel use 10 percent (beyond that achieved by EERS and CHP) by 2030.	1.7	0.36	2.58
Rural energy efficiency: The federal government expands its farm bill Section 9006 technical assistance grants.	0.01	0.003	0.02
Petroleum feedstocks: Wider use of recycled feedstocks cuts industrial use of petroleum feedstocks 20 percent by 2030.	0.3	0.02	0.15
TOTAL	12.1	13.40	113.55

the economy.[39] The federal government abandoned many of those efforts in the early 1990s, when the price of electricity dropped and many states deregulated electricity markets. Only with the Farm Security and Rural Investment Act of 2002, known as the farm bill, did rural energy efficiency programs begin to reappear (Brown, Elliott, and Nadel 2005).

The Blueprint assumes that Section 9006 of the farm bill would continue. That section mandates annual grants of $35 million—including more than 40,000 individual grants—to provide technical assistance to farmers, to encourage them to rely on renewable energy and improve their energy efficiency. Under the Blueprint, such programs would enable farmers to cut their energy use 10–30 percent.

4.6.9. Use of Recycled Petroleum Feedstocks

The Blueprint builds on existing mandates for recycling plastics and other petrochemical products, and also assumes that research on using recycled materials in industrial processes would expand. The result is that the use of petroleum in industrial feedstocks drops a total of 12 percent by 2020, and 20 percent by 2030. These cuts are consistent with the impact of mandated plastic-recycling efforts in Germany (Elliott, Langer, and Nadel 2006).

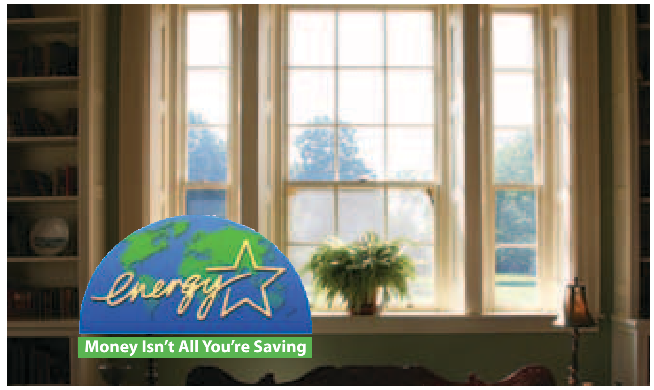
4.7. The Bottom Line

Energy efficiency is the quickest, most cost-effective strategy for delivering significant and sustained cuts in carbon emissions. Innovative technologies and common-sense measures are available now, and can transform how our industries and buildings use energy over the next two decades (see Table 4.3). However, the nation needs to implement a suite of policies that builds on leading experiences at the state and federal level, to remove key barriers and stimulate investment. Once implemented, these policies can reduce total U.S. energy consumption 29 percent by 2030 while providing significant cost savings to consumers.

39 Because energy expenses account for up to 10 percent of a farm's budget, changes in energy costs can significantly affect the viability of operations in this low-profit-margin sector (Brown, Elliot, and Nadel 2005).

BOX 4.3.

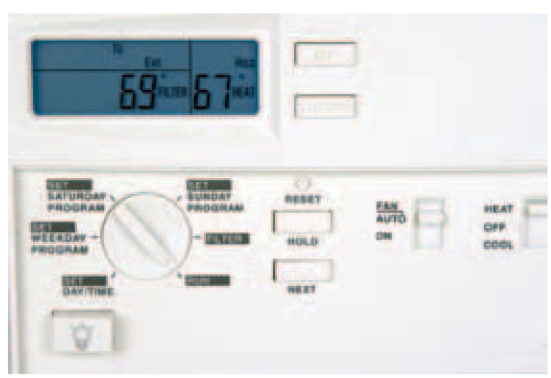
The Many Faces of Energy Efficiency



Windows labeled "Low-E" keep buildings warmer in the winter and cooler in the summer. Energy Star labels help consumers identify the most energy-efficient products.

A blower-door test finds leaks that can be sealed, creating an airtight building with minimal heat and air-conditioning loss.

A properly sized HVAC system with centrally located ducts eliminates heat loss.



Programmable thermostats reduce energy use when residents are sleeping or not home.