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4

Stabilizing Climate: An Energy Efficiency Revolution

The world is in the early stages of two energy revolutions. The first is a shift to new energy-efficient technologies across the board. The larger energy savings potentials include shifting from century-old technologies such as incandescent light bulbs and internal combustion engines to far more efficient technologies. Incandescents are being replaced by compact fluorescent bulbs that use one fourth as much electricity. This in turn will be cut in half by the light-emitting diodes (LEDs) coming on the market. And the most advanced plug-in hybrid car prototypes use only one fifth as much gasoline per mile as the average U.S. car on the road today.

The second energy revolution—the shift from an economy powered by oil, coal, and natural gas to one powered by wind, solar, and geothermal energy—is under way and moving fast. In Europe, new electrical generating capacity from wind, solar, and other renewables now exceeds that from fossil fuels by a wide margin. In the United States, new wind-generating capacity of 8,400 megawatts in 2008 dwarfed the 1,400 megawatts from coal. Nuclear power is fading, too. Worldwide, nuclear power generation actually declined in 2008 while wind electric generating capacity increased by 27,000 megawatts, enough to supply 8 million American homes. The world is changing fast.[1]

This chapter begins with a brief description of Plan B's goal of cutting net carbon emissions and then describes in detail the components of the first revolution—the push to raise energy efficiency worldwide. Chapter 5 describes the transition to an economy powered largely by wind, solar, and geothermal energy.

Implementing Plan B entails cutting net carbon dioxide (CO_2) emissions 80 percent by 2020. This would keep atmospheric CO_2 levels from exceeding 400 parts per million (ppm), up only modestly from 386 ppm in 2008.[2]

This sets the stage for reducing CO_2 concentrations to the 350 ppm that James Hansen and other climate scientists think is needed to avoid runaway climate change. It will also help keep future temperature rise to a minimum. Such a basic economic restructuring in time to avoid catastrophic climate disruption will be challenging, but how can we face the next generation if we do not try?[3]

This restructuring of the world energy economy is being driven by some traditional concerns and some newer ones. Among the former are mounting concerns over climate change, a growing sense of oil insecurity, the rising level and volatility of fossil fuel prices, and financial outlays for importing oil.

The recent global economic downturn and the record number of young people entering job markets in developing countries has also made labor intensity a goal of energy policymaking. Improving energy efficiency and developing renewable sources of energy are both much more labor-intensive than burning fossil fuels. Closely associated with this is the realization that the countries and companies that are at the forefront of developing new energy technologies will have a strong competitive advantage in world markets.[4]

The energy component of Plan B is straightforward. We raise world energy efficiency enough to at least offset all projected growth in energy use from now until 2020. We also turn to wind, solar, geothermal, and other renewable sources to largely replace oil, coal, and natural gas. In effect, Plan B outlines the transition from fossil fuels to renewable sources of energy by 2020. Difficult? Yes. Impossible? No!

Stephen Pacala and Robert Socolow at Princeton University set the stage for Plan B in 2004 when they published an article in *Science* that showed how annual carbon emissions from burning fossil fuels could be held at 7 billion tons instead of rising to 14 billion tons over the next 50 years, as would occur with business as usual. Their goal was to prevent atmospheric CO_2 concentrations, then near 375 ppm, from rising above 500 ppm.[5]

Pacala and Socolow described 15 proven technologies, including efficiency gains and new energy from various renewables, that could each cut carbon emissions 1 billion tons per year by 2054. Any 7 of these options could be combined to prevent an increase in carbon emissions from now through 2054. They further theorized that advancing technology would allow annual carbon emissions to be cut to 2 billion tons by 2104, a level that could likely be absorbed by natural carbon sinks on land and in the oceans.[6]

The Pacala/Socolow exercise was neither a plan nor a projection but a conceptualization, one that has been extraordinarily useful in helping analysts think about the future relationship between energy and climate. Now it is time to select the most promising energy technologies and structure an actual plan to cut carbon emissions. And since climate is changing much faster than anticipated even a few years ago, we believe the world needs to halt the rise in CO_2 levels not at 500 ppm in 2054 but at 400 ppm in 2020. First we look at the enormous potential for raising energy efficiency in the lighting sector.[7]

A Revolution in Lighting Technology

Since the lighting sector is on the edge of a spectacular revolution based on new technologies, perhaps the quickest, most profitable way to reduce electricity use worldwide is simply to change light bulbs.

The first advance in this field came with compact fluorescent lamps (CFLs), which use 75 percent less electricity than old-fashioned incandescents. Replacing inefficient incandescent bulbs that are still widely used today with new CFLs can reduce the electricity used for lighting by three fourths. Over its lifetime, each standard (13 watt) CFL will reduce electricity bills by roughly $30. And though a CFL may cost twice as much as an incandescent, it lasts 10 times as long. Each one reduces energy use compared with an incandescent by the equivalent of 200 pounds of coal over its lifetime. For perspective, the energy saved by replacing a 100-watt incandescent bulb with an equivalent CFL over its lifetime is sufficient to drive a Toyota Prius hybrid car from New York to San Francisco.[8]

CFL production in China, which accounts for 85 percent of the world total, climbed from 750 million units in 2001 to 2.4 billion units in 2006. Sales in the United States climbed from 21 million CFLs in 2000 to 397 million in 2007. Of the estimated 4.7 billion light sockets in the United States, close to 1 billion now have CFLs.[9]

The world may be moving toward a political tipping point to replace inefficient light bulbs across the board. In February 2007 Australia announced it would phase out the sale of incandescents by 2010, replacing them with CFLs. Canada soon followed with a 2012 phaseout goal. In early 2009, the European Union (EU) approved a phaseout of incandescent bulbs, one that will save the average EU consumer 25–50 euros each year.[10]

Brazil, hit by a nationwide electricity shortage in 2000–02, responded with an ambitious program to replace incandescents with CFLs. As a result, an estimated half of the light sockets there now contain these efficient bulbs. In 2007, China—working with the Global Environment Facility—announced a plan to replace all its incandescents with more-efficient lighting within a decade. And India is planning to phase out incandescent bulbs by 2012.[11]

Retailers are joining the switch too. Wal-Mart, the world's largest retailer, began an ambitious marketing campaign in 2007 to boost its cumulative U.S. sales of compact fluorescents to over 260 million. Currys, Britain's largest electrical retail chain, went further—discontinuing sales of incandescent light bulbs in 2007.[12]

For office buildings, commercial outlets, and factories, where linear (tubular) fluorescents are widely used, the key to cutting electricity use is shifting to the most advanced models, which are even more efficient than CFLs. However, since linear fluorescents are long-lasting, many of those now in use rely on an earlier, less energy-efficient technology.

The second major advance in lighting technology is the light-emitting diode, which uses up to 85 percent less electricity than incandescents. Although LEDs are the ultimate in lighting efficiency, they are still too costly for most uses. They are rapidly

taking over several niche markets, however, such as traffic lights, where they now have 52 percent of the U.S. market, and exit signs in buildings, where they hold 88 percent of U.S. sales. New York City has replaced traditional bulbs with LEDs in many of its traffic lights, cutting its annual bill for maintenance and electricity by $6 million. In early 2009, Los Angeles Mayor Antonio Villaraigosa said the city would replace its 140,000 street lights with LEDs, saving taxpayers $48 million over the next seven years. The resulting reduction in carbon emissions would be like taking 7,000 cars off the road.[13]

Universities are also getting involved. In California, the University of California-Davis has a Smart Lighting Initiative. One of its first projects was to replace all the light bulbs in a campus parking garage with LEDs, dramatically reducing electricity use. This success has evolved into LED University, a project to disseminate this technology. Early adopters include the University of California-Santa Barbara, Tianjin Polytechnic University in China, and the University of Arkansas.[14]

LEDs offer another strong economic advantage. While CFLs last 10 times as long as incandescents, LEDs last 50 times as long. Indeed, a typical LED installed at the time of a child's birth will still be working when the youngster graduates from college. The savings in commercial situations from both lower electricity costs and the virtual elimination of replacement maintenance often more than offsets the higher initial cost.[15]

In addition to switching bulbs, energy can be saved just by turning lights off when they are not in use. There are numerous technologies for doing this, including motion sensors that turn lights off in unoccupied offices, living rooms, washrooms, hallways, and stairwells. Sensors and dimmers can also be used to take advantage of daylighting to reduce the intensity of interior lighting when sunlight is bright. In cities, dimmers can be used to reduce streetlight intensity. In fact, these smart lighting technologies can cut the electricity use of LEDs to less than 10 percent of that with incandescents.[16]

In summary, shifting to CFLs in homes, to the most advanced linear fluorescents in office buildings, commercial outlets, and factories, and to LEDs in traffic lights would cut the world share of electricity used for lighting from 19 percent to 7 percent. This would save enough electricity to close 705 of the world's 2,670 coal-fired plants. If the high cost of LEDs drops faster than we have assumed, making widespread use feasible, lighting efficiency gains will come even faster than we have projected.[17]

In a world facing almost daily new evidence of climate change and its consequences, a quick and decisive victory is needed in the battle to cut carbon emissions and stabilize climate. A rapid shift to the most energy-efficient lighting technologies would provide just such a victory—generating momentum for even greater advances in climate stabilization.

Energy-Efficient Appliances

Just as CFLs offer great electricity savings over incandescent light bulbs, a similar range of efficiencies is available for many household appliances, such as refrigerators. The U.S. Energy Policy Act of 2005 was designed to exploit some of these potential savings by raising appliance efficiency standards enough to close 29 coal-fired power plants. Other provisions in the act—such as tax incentives that encourage the adoption of energy-efficient technologies, a shift to more combined heat and power generation, and the adoption of real-time pricing of electricity (a measure to discourage optional electricity use during peak demand periods)—would cut electricity demand enough to close an additional 37 coal-fired power plants. Appliance efficiency standards and other measures in the bill would also reduce natural gas consumption substantially. Altogether, these measures are projected to reduce consumer electricity and gas bills in 2020 by more than $20 billion.[18]

Although the U.S. Congress passed legislation raising efficiency for some 30 categories of household and industrial appliances—from refrigerators to industrial-scale electric motors—the U.S. Department of Energy (DOE) has for many years failed to write the standards needed to actually implement the legislation. To remedy this, just days after taking office President Barack Obama ordered the DOE to write regulations to translate law into policy.[19]

With appliances, the big challenge is China. In 1980 its appliance manufacturers produced only 50,000 refrigerators, virtually all for domestic use. In 2008 they produced 48 million refrigerators, 90 million color TVs, and 42 million clothes washers, many of which were for export.[20]

Market penetration of these modern appliances in urban China today is already similar to that in industrial countries. For every 100 urban households there are 138 color TV sets, 97 washing machines, and 88 room air conditioners. Even in rural areas there are 95 color TVs and 46 washing machines for every 100 households. This phenomenal growth in household appliance use in China, along with the extraordinary growth of industry, raised China's electricity use 11-fold from 1980 to 2007. Although China established standards for most appliances by 2005, these are not strictly enforced.[21]

The other major concentration of home appliances is in the European Union, home to 495 million people. Greenpeace notes that even though Europeans on average use half as much electricity as Americans do, they still have a large potential for reducing their usage. A refrigerator in Europe uses scarcely half as much electricity as one in the United States, for example, but the most efficient refrigerators on the market today use only one fourth as much electricity as the average refrigerator in Europe, suggesting a huge potential for cutting electricity use.[22]

But this is not the end of the efficiency trail, since advancing technology keeps raising the potential. Japan's Top Runner Program is the world's most dynamic system for upgrading appliance efficiency standards. In this system, the most efficient appliances marketed today set the standard for those sold tomorrow. Using this program, between the late 1990s and the end of 2007 Japan raised efficiency standards for individual appliances by anywhere from 15 to 83 percent, depending on the appliance. This is an ongoing process that continually exploits advances in efficiency technologies. A 2008 report indicates that the Top Runner Program for all appliances is running ahead of the ambitious initial expectations—and often by a wide margin.[23]

In an analysis of potential energy savings by 2030 by type of appliance, the Organisation for Economic Co-operation and Development (OECD) put the potential savings from reducing electricity for standby use—the power consumed when an appliance is not being used—at the top of the list. The electricity used by appliances in standby mode worldwide accounts for up to 10 percent of total electricity consumption. In OECD countries, individual household standby power ranged from a low of perhaps 30 watts to a high of over 100 watts in both U.S. and

New Zealand households. Since this power is used around the clock, even though the wattage is relatively low, the cumulative use is substantial.[24]

Some governments are capping standby power use by TV sets, computers, microwaves, DVD players, and so on at 1 watt per appliance. South Korea, for example, is mandating a 1-watt limit on standby for many appliances by 2010. Australia is doing the same for nearly all appliances by 2012.[25]

A U.S. study estimates that roughly 5 percent of U.S. residential electricity use is from appliances in standby mode. If this figure dropped to 1 percent, which could be done easily, 17 coal-fired power plants could be closed. If China were to lower its standby losses to 1 percent, it could close a far larger number of power plants.[26]

A more recent efficiency challenge has come with the market invasion of large, flat-screen televisions. The screens now on the market use easily twice as much electricity as a traditional cathode ray tube television. If the flat screen is a large-screen plasma model, it can use four times as much electricity. In the United Kingdom, some Cabinet members are proposing to ban the energy-guzzling flat-screen plasma televisions. California is proposing that all new televisions draw one third less electricity than current sets by 2011 and 49 percent less by 2013.[27]

Consumers often do not buy the most energy-efficient appliances because the initial purchase price is higher, even though this is more than offset by lower appliance lifetime operating costs. If, however, societies adopt a carbon tax reflecting the costs of climate change, the more efficient appliances would be economically much more attractive. Energy use labeling requirements would help consumers choose more wisely.

A worldwide set of appliance efficiency standards keyed to the most efficient models on the market would lead to energy savings in the appliance sector approaching or exceeding the 12 percent of world electricity savings from more-efficient lighting. Thus the combined gains in lighting and appliance efficiencies alone would enable the world to avoid building 1,410 coal-fired power plants—more than the 1,283 new coal-fired power plants that the International Energy Agency (IEA) projects will be built by 2020.[28]

Zero-Carbon Buildings

The building sector is responsible for a large share of world electricity consumption and raw materials use. In the United States, buildings—commercial and residential—account for 72 percent of electricity use and 38 percent of CO_2 emissions. Worldwide, building construction accounts for 40 percent of materials use.[29]

Because buildings last for 50–100 years or longer, it is often assumed that cutting carbon emissions in the building sector is a long-term process. But that is not the case. An energy retrofit of an older inefficient building can cut energy use and energy bills by 20–50 percent. The next step, shifting entirely to carbon-free electricity, either generated onsite or purchased, to heat, cool, and light the building completes the job. Presto! A zero-carbon operating building.[30]

The building construction and real estate industries are recognizing what an Australian firm, Davis Langdon, calls "the looming obsolescence of non-green buildings"—one that is driving a wave of reform in both construction and real estate. Further, Davis Langdon says, "going green is future-proofing your asset."[31]

Some countries are taking bold steps. Notable among them is Germany, which as of January 2009 requires that all new buildings either get at least 15 percent of space and water heating from renewable energy or dramatically improve energy efficiency. Government financial support is available for owners of both new and existing buildings for installing renewable energy systems or making efficiency improvements. In reality, once builders or home owners start to plan these installations, they will quickly see that in most cases it makes economic sense to go far beyond the minimal requirements.[32]

There are already signs of progress in the United States. In February 2009, the U.S. Congress passed—and the President signed—the American Recovery and Reinvestment Act, legislation designed to stimulate the U.S. economy. Among other items, it provides for the weatherization of more than a million homes, beginning with an energy audit to identify the measures that would quickly reduce energy use. A second part calls for the weatherization and retrofitting of a large share of the nation's stock of public housing. A third component is the greening of government buildings by making them more energy-efficient and, wherever possible, installing devices such as rooftop solar water and space heaters and rooftop solar electric arrays. The combination of these initiatives is intended to help build a vigorous new industry that would play an active role in raising U.S. energy efficiency and cutting carbon emissions.[33]

In the private sector, the U.S. Green Building Council (USGBC)—well known for its Leadership in Energy and Environmental Design (LEED) certification and rating program—heads the field. This voluntary program, which sets standards well above those of the U.S. government Energy Star building certification program, has four certification levels—certified, silver, gold, and platinum. A LEED-certified building must meet minimal standards in environmental quality, materials use, energy efficiency, and water efficiency. LEED-certified buildings are attractive to buyers because they have lower operating costs, higher lease rates, and typically happier, healthier occupants than traditional buildings do.[34]

The LEED certification standards for construction of new buildings were issued in 2000. Any builder who wants a structure to be rated must request and pay for certification. In 2004 the USGBC also began certifying the interiors of commercial buildings and tenant improvements of existing buildings. And in 2007 it began issuing certification standards for home builders.[35]

Looking at the LEED criteria provides insight into the many ways buildings can become more energy-efficient. The certification process for new buildings begins with site selection, and then moves on to energy efficiency, water efficiency, materials use, and indoor environmental quality. In site selection, points are awarded for proximity to public transport, such as subway, light rail, or bus lines. Beyond this, a higher rating depends on provision of bicycle racks and shower facilities for employees. New buildings must also maximize the exposure to daylight, with minimum daylight illumination for 75 percent of the occupied space.[36]

With energy, exceeding the high level of efficiency required for basic certification earns additional points. Further points are awarded for the use of renewable energy, including rooftop solar cells to generate electricity, rooftop solar water and space heaters, and the purchase of green power.[37]

Thus far LEED has certified 1,600 new buildings in the United States, with some 11,600 planned or under construction that have applied for certification. The commercial building space that has been certified or registered for certification approval totals 5 billion square feet of floor space, or some 115,000 acres (the equivalent of 115,000 football fields).[38]

The Chesapeake Bay Foundation's office building for its 100 staff members near Annapolis, Maryland, was the first to earn a LEED platinum rating. Among its features are a ground-source heat pump for heating and cooling, a rooftop solar water heater, and sleekly designed composting toilets that produce a rich humus used to fertilize the landscape surrounding the building.[39]

Toyota's North American headquarters in Torrance, California, which houses 2,000 employees, has a LEED gold rating and is distinguished by a large solar-electric generating facility that provides much of its electricity. Waterless urinals and rainwater recycling enable it to operate with 94 percent less water than a conventionally designed building of the same size. Less water use also means less energy use.[40]

The 54-story Bank of America tower in New York is the first large skyscraper expected to earn a platinum rating. It has its own co-generation power plant and collects rainwater, reuses waste water, and used recycled materials in construction.[41]

A 60-story office building with a gold rating being built in Chicago will use river water to cool the building in summer, and the rooftop will be covered with plants to reduce runoff and heat loss. Energy-conserving measures will save the owner $800,000 a year in energy bills. The principal tenant, Kirkland and Ellis LLP, a Chicago-based law firm, insisted that the building be gold-certified and that this be incorporated into the lease.[42]

The state of California commissioned Capital E, a green building consulting firm, to analyze the economics of 33 LEED-certified buildings in the state. The study concluded that certification raised construction costs by $4 per square foot but that because operating costs as well as employee absenteeism and turnover were lower and productivity was higher than in other buildings, the standard- and silver-certified buildings earned a profit over the first 20 years of $49 per square foot, and the gold- and platinum-certified buildings earned $67 per square foot.[43]

In 2002 a global version of the USGBC, the World Green Building Council, was formed. As of spring 2009 it included Green Building Councils in 14 countries, including Brazil, India, and the United Arab Emirates. Eight other countries—ranging from Spain to Viet Nam—are working to meet the prerequisites for membership. Among the current members, India ranks second in certification after the United States, with 292 million square feet of LEED-certified floor space, followed by China (287 million) and Canada (257 million).[44]

Beyond greening new buildings, there are numerous efforts to make older structures more efficient. In 2007, the Clinton Foundation announced an Energy Efficiency Building Retrofit Program, a project of the Clinton Climate Initiative. In cooperation with C40, a large-cities climate leadership group, this program brings together five of the world's largest banks and four leading energy service companies to work with an initial group of 16 cities to retrofit buildings, reducing their energy use by 20–50 percent. Among the cities are some of the world's largest: Bangkok, Berlin, Karachi, London, Mexico City, Mumbai, New York, Rome, and Tokyo. Each of the banks involved—ABN AMRO, Citi, Deutsche Bank, JP Morgan Chase, and UBS—is committed to investing up to $1 billion in this effort, enough to easily double the current worldwide level of energy saving retrofits.[45]

The energy service companies—Honeywell, Johnson Controls, Siemens, and Trane—committed not only to do the actual retrofitting but also to provide "performance guarantees," thus ensuring that all the retrofits will be profitable. At the launch of this program, former President Bill Clinton pointed out that banks and energy service companies would make money, building owners would save money, and carbon emissions would fall. As of February 2009, the Clinton Climate Initiative had been involved with 250 retrofit projects and over 500 million square feet of floor space.[46]

In April 2009, the owners of New York's Empire State Building announced plans to retrofit the 2.6 million square feet of office space in the nearly 80-year-old 102-story building, thereby reducing its energy use by nearly 40 percent. The resulting energy savings of $4.4 million a year is expected to recover the retrofitting costs in three years.[47]

Beyond these voluntary measures, the government-designed

building codes, which set minimal standards for building energy efficiency, are highly effective. In the United States this has been dramatically demonstrated in differences between California and the country as a whole in housing energy efficiency. Between 1975 and 2002, residential energy use per person dropped 16 percent in the country as a whole. But in California, which has stringent building codes, it dropped by 40 percent. The bottom line is that there is an enormous potential for reducing energy use in buildings in the United States and, indeed, the world.[48]

One firm believer in that potential is Edward Mazria, a climate-conscious architect from New Mexico. He has launched the 2030 Challenge. Its principal goal is for U.S. architects to be designing buildings in 2030 that use no fossil fuels. Mazria observes that the buildings sector is the leading source of carbon emissions, easily eclipsing transportation. Therefore, he says, "it's the architects who hold the key to turning down the global thermostat." To reach his goal, Mazria has organized a coalition of several organizations, including the American Institute of Architects, the USGBC, and the U.S. Conference of Mayors.[49]

Mazria also recognizes the need for faculty retraining in the country's 124 architectural schools to "transform architecture from its mindless and passive reliance on fossil fuels to an architecture intimately linked to the natural world in which we live."[50]

Today's architectural concepts and construction technologies enable architects to easily design new buildings with half the energy requirements of existing ones. Among the design technologies they can use are natural daylighting, rooftop solar-electric cells, rooftop solar water and space heaters, ultra insulation, natural ventilation, ground source heat pumps, glazed windows, waterless urinals, more-efficient lighting technologies, and motion sensors for lighting. Designing and constructing energy-efficient buildings, combined with a massive harnessing of renewable energy, makes it not only possible but also profitable for buildings to operate without fossil fuels.[51]

Electrifying the Transport System

Among the keys to cutting carbon emissions are redesigning urban transport (see Chapter 6) and the overall electrification of transportation. The last century witnessed the evolution of an oil-powered transport system: gasoline for cars and diesel fuel for trucks and trains. Now that is changing. With both cars and rail systems, oil will be replaced by electricity. And the power will come increasingly from wind farms and from solar and geothermal power plants.

With peak oil on our doorstep, the world desperately needs a new automotive energy economy. Fortunately, the foundation for this has been laid with two new technologies: gas-electric hybrid plug-in cars and all-electric cars.

The Toyota Prius—the world's top-selling hybrid car—gets an impressive 50 miles per gallon (mpg) in combined city/highway driving, nearly double that of the average new U.S. passenger vehicle. The United States could easily cut its gasoline use in half simply by converting the entire American automobile fleet to highly efficient hybrid cars. But this is only the beginning.[52]

Now that hybrid cars are well established, it is a relatively small additional step to manufacture plug-in hybrids that run largely on electricity. By shifting to lithium ion batteries to boost electricity storage capacity and by adding an extension cord so the battery can be recharged from the grid, drivers can do their commuting, grocery shopping, and other short-distance travel almost entirely with electricity, using gasoline only for the occasional long trip. Even more exciting, recharging batteries with off-peak wind-generated electricity costs the equivalent of less than $1 per gallon of gasoline.[53]

As of mid-2009, nearly all major car makers have announced plans to bring either plug-in hybrids or all-electric cars to market. The world's first commercially available plug-in hybrid car reached the market in December 2008 in China. While the world was focusing on the race between Toyota and GM, China's BYD (Build Your Dreams) had quietly forged ahead, bringing its plug-in hybrid car to market. Already in mass production and selling for a highly competitive $22,000, it is scheduled to appear in U.S. and European markets in 2010.[54]

Meanwhile, Toyota apparently has gotten the jump on GM by announcing it would start to market a limited number of plug-in hybrids for selected use by the end of 2009. The Chevrolet Volt, GM's entry, is expected to average 150 mpg, largely because of a stronger battery and greater all-electric range. It is

this prospect of triple-digit gasoline mileage that is selling customers on plug-in hybrids.[55]

Nissan has been emphasizing the development of an all-electric car, which it plans to market in 2010. Chrysler plans to produce an electric version of several of its models, effectively offering customers a choice between gasoline and electrically powered vehicles. Think, an entrepreneurial Norwegian firm, already producing an all-electric car in Norway, is planning an assembly plant in the United States in 2010 to produce up to 60,000 electric cars per year.[56]

Shifting to plug-in electric hybrids and all-electric cars does not require a costly new infrastructure, since the network of gasoline service stations and the electricity grid are already in place. A 2006 study by the U.S. Pacific Northwest National Laboratory estimated that over 80 percent of the electricity needs of a national fleet of all plug-in cars could be satisfied with the existing electrical infrastructure since the recharging would take place largely at night, when there is an excess of generating capacity. What will be needed is the installation of electrical outlets in parking garages, parking lots, and street-side parking meters, along with a credit card access device to identify the user for billing purposes.[57]

Silicon Valley entrepreneur Shai Agassi is working with Nissan and the governments of Israel, Denmark, Australia, and Canada's Ontario Province, as well as the San Francisco Bay area of California and Hawaii in the United States, to set up networks of electric-car service stations. These stations would replace depleted batteries with freshly charged ones, thus eliminating the need for time-consuming recharges. Whether the typical daily driving distance will warrant investment in battery replacement on this scale remains to be seen.[58]

While the future of transportation in cities lies with a mix of light rail, buses, bicycles, some cars, and walking, the future of intercity travel belongs to high-speed trains. Japan, with its bullet trains, pioneered this mode of travel. Operating at speeds up to 190 miles per hour, Japan's bullet trains carry almost a million passengers a day. On some of the heavily used intercity high-speed lines, trains depart every three minutes.[59]

Beginning in 1964 with the 322-mile line from Tokyo to Osaka, Japan's high-speed rail network now stretches for 1,360 miles, linking nearly all its major cities. One of the most heavily traveled links is the original line, where the bullet trains carry 413,000 passengers a day. The transit time of two-and-a-half hours between Tokyo and Osaka compares with a driving time of eight hours. High-speed trains save time as well as energy.[60]

Although Japan's bullet trains have carried billions of passengers in great comfort over 40 years at high speeds, there has not been a single casualty. Late arrivals average 6 seconds. If we were selecting seven wonders of the modern world, Japan's high-speed rail system surely would be among them.[61]

Although the first European high-speed line, from Paris to Lyon, did not begin operation until 1981, Europe has made enormous strides since then. As of 2009 there were 3,100 miles (5,000 kilometers) of high-speed rail operating in Europe. The goal is to triple this track length by 2020 and eventually to integrate the eastern countries, including Poland, the Czech Republic, and Hungary, into a continental network.[62]

While France and Germany were the early European leaders in intercity rail, Spain is fast building a high-speed intercity rail network as well. Within a year of opening the Barcelona-to-Madrid connection, domestic airlines lost roughly a fifth of their passengers to these high-speed intercity trains. Spain plans to link with high-speed systems in France to become firmly integrated into the European network.[63]

Existing international links, such as the one between Paris and Brussels, are being joined by connections between Paris and Stuttgart, Frankfurt and Paris, and London and Paris (the latter via the Channel Tunnel). On the newer lines, trains are operating at up to 200 miles per hour. As *The Economist* notes, "Europe is in the grip of a high speed rail revolution."[64]

High-speed links between cities dramatically raise rail travel. For example, when the Paris-to-Brussels link opened—the 194 miles is covered by train in just 85 minutes—the share of those traveling between the two cities by train rose from 24 percent to 50 percent. The car share dropped from 61 to 43 percent, and plane travel virtually disappeared.[65]

Carbon dioxide emissions per passenger mile on electric high-speed trains are roughly one third those of cars and one fourth those of planes. In the Plan B economy, carbon emissions from trains will essentially be zero, since they will be powered

almost entirely by renewable electricity. In addition to being comfortable and convenient, these rail links reduce air pollution, congestion, noise, and accidents. They also free travelers from the frustrations of traffic congestion and long airport security check lines.[66]

There is a huge gap in high-speed rail between Japan and Europe on the one hand and the rest of the world on the other. But China is beginning to develop high-speed trains linking some of its major cities. A high-speed link between Beijing and Shanghai scheduled for completion by 2013 will slice train travel time in half, from 10 to 5 hours. China now has 3,890 miles of track that can handle train speeds of up to 125 miles per hour. The plan is to triple the length of high-speed track by 2020.[67]

The United States has a "high-speed" Acela Express that links Washington, New York, and Boston, but unfortunately neither its rail bed and speed nor its reliability come close to the trains in Japan and Europe. The good news is that the U.S. economic stimulus plan signed into law in February 2009 contained some $8 billion to help launch a new era of high-speed rail construction in the United States.[68]

In the United States, the need to cut carbon emissions and prepare for shrinking oil supplies calls for this shift in investment from roads and highways to railways. In 1956 U.S. President Dwight Eisenhower launched the interstate highway system, justifying it on national security grounds. Today the threat of climate change and the insecurity of oil supplies argue for the construction of a high-speed electrified rail system, for both passenger and freight traffic. The additional electricity needed could easily be supplied from renewable sources, mainly wind energy.[69]

The passenger rail system would be modeled after those of Japan and Europe. A high-speed transcontinental line that averaged 170 miles per hour would mean traveling coast-to-coast in 15 hours, even with stops in major cities along the way. There is a parallel need to develop an electrified national rail freight network that would greatly reduce the need for long-haul trucks.

Voters in California approved a bond referendum in November 2008 of nearly $10 billion to build a high-speed rail system to link northern and southern California. This would reduce the use of cars and eliminate many of the fuel-guzzling short-distance flights linking California's major cities.[70]

Any meaningful global effort to cut transport carbon emissions begins with the United States, which consumes more gasoline than the next 20 countries combined (including Japan, China, Russia, Germany, and Brazil). The United States—with 249 million passenger vehicles out of the global 912 million—not only has the largest fleet but it is near the top in miles driven per car and near the bottom in fuel efficiency.[71]

The first step to reduce this massive U.S. consumption of gasoline is to raise fuel efficiency standards. The 40-percent increase in these standards by 2016 announced by the Obama administration in May 2009 will greatly reduce U.S. gasoline use and bring the country closer to the fuel economy levels prevailing in Europe and China. A crash program to shift the U.S. fleet to plug-in hybrids and all-electric cars would make an even greater contribution. And shifting public funds from highway construction to public transit would reduce the number of cars needed, bringing us close to our goal of cutting carbon emissions 80 percent by 2020.[72]

A New Materials Economy

The production, processing, and disposal of materials in our modern throwaway economy wastes not only materials but energy as well. In nature, one-way linear flows do not survive long. Nor, by extension, can they survive long in the expanding global economy. The throwaway economy that has evolved over the last half-century is an aberration, now itself headed for the junk heap of history.

The potential for sharply reducing materials use was first identified in Germany, initially by Friedrich Schmidt-Bleek in the early 1990s and then by Ernst von Weizsäcker, an environmental leader in the German Bundestag. They argued that modern industrial economies could function very effectively using only one fourth the virgin raw materials prevailing at the time. A few years later, Schmidt-Bleek, who founded the Factor Ten Institute in France, showed that raising resource productivity even more—by a factor of 10—was well within the reach of existing technology and management, given the right policy incentives.[73]

In their book *Cradle to Cradle: Remaking the Way We Make Things*, American architect William McDonough and German chemist Michael Braungart conclude that waste and pollution are to be avoided entirely. "Pollution," says McDonough, "is a symbol of design failure."[74]

Beyond reducing materials use, the energy savings from recycling are huge. Steel made from recycled scrap takes only 26 percent as much energy as that from iron ore. For aluminum, the figure is just 4 percent. Recycled plastic uses only 20 percent as much energy. Recycled paper uses 64 percent as much—and with far fewer chemicals during processing. If the world recycling rates of these basic materials were raised to those already attained in the most efficient economies, carbon emissions would drop precipitously.[75]

Industry, including the production of plastics, fertilizers, steel, cement, and paper, accounts for more than 30 percent of world energy consumption. The petrochemical industry, which produces such things as plastics, fertilizer, and detergents, is the biggest consumer of energy in the manufacturing sector, accounting for about a third of worldwide industrial energy use. Since a large part of industry fossil fuel use is for feedstock to manufacture plastics and other materials, increased recycling can reduce feedstock needs. Worldwide, increasing recycling rates and moving to the most efficient manufacturing systems in use today could easily reduce energy use in the petrochemical industry by 32 percent.[76]

The global steel industry, producing over 1.3 billion tons in 2008, accounts for 19 percent of industrial energy use. Efficiency measures, such as adopting the most efficient blast furnace systems in use today and the complete recovery of used steel, could reduce energy use in the steel industry by 23 percent.[77]

Reducing materials use begins with recycling steel, the use of which dwarfs that of all other metals combined. Steel use is dominated by three industries—automobile, household appliances, and construction. In the United States, virtually all cars are recycled. They are simply too valuable to be left to rust in out-of-the-way junkyards. The U.S. recycling rate for household appliances is estimated at 90 percent. For steel cans it is 63 percent, and for construction steel the figures are 98 percent for steel beams and girders but only 65 percent for reinforcement steel. Still, the steel discarded each year in various forms is enough to meet the needs of the U.S. automobile industry.[78]

Steel recycling started climbing more than a generation ago with the advent of the electric arc furnace, a technology that produces steel from scrap using only one fourth the energy required to produce it from virgin ore. Electric arc furnaces using scrap now account for half or more of steel production in more than 20 countries. A few countries, including Venezuela and Saudi Arabia, use electric arc furnaces exclusively. If three fourths of steel production were to switch to electric arc furnaces using scrap, energy use in the steel industry could be cut by almost 40 percent.[79]

The cement industry, turning out 2.9 billion tons in 2008, is another major energy consumer. China, accounting for half of world production, manufactures more cement than the next 20 countries combined, yet it does so with extraordinary inefficiency. If China used the same kiln technologies as Japan, it could reduce its cement production energy use by 45 percent. Worldwide, if all cement producers used the most efficient dry kiln process, energy use in the industry could drop 42 percent.[80]

Restructuring the transportation system also has a huge potential for reducing materials use as light rail and buses replace cars. For example, improving urban transit means that one 12-ton bus can easily replace 60 cars weighing 1.5 tons each, or a total of 90 tons, reducing material use 87 percent. And every time someone replaces a car with a bike, material use is reduced 99 percent.[81]

The big challenge for cities in saving energy is to recycle as many components of the urban waste flow as possible. Virtually all paper products can now be recycled, including cereal boxes, junk mail, and paper bags in addition to newspapers and magazines. So too can metals, glass, and most plastics. Kitchen and yard waste can be composted to recycle plant nutrients.

Advanced industrial economies with stable populations, such as those in Europe and Japan, can rely primarily on the stock of materials already in the economy rather than using virgin raw materials. Metals such as steel and aluminum can be used and reused indefinitely.[82]

In the United States, the latest *State of Garbage in America* report shows that 29 percent of garbage is recycled, 7 percent is burned, and 64 percent goes to landfills. Recycling rates among U.S. cities vary from less than 30 percent in some cities to more than 70 percent in San Francisco, the highest in the country. When San Francisco hit 70 percent in 2008, Mayor Gavin Newsom immediately announced a plan to reach 75 percent. Among the largest U.S. cities, recycling rates vary from 34 percent in New York to 55 percent in Chicago and 60 percent in Los Angeles. At the state level, Florida has boldly set a goal of recycling 75 percent of waste by 2020.[83]

One of the most effective ways to encourage recycling is to adopt a landfill tax. For example, when the state of New Hampshire adopted a "pay-as-you-throw" program that encourages municipalities to charge residents for each bag of garbage, it dramatically reduced the flow of materials to landfills. In the small town of Lyme, with nearly 2,000 people, adoption of a landfill tax raised the share of garbage recycled from 13 to 52 percent in one year.[84]

The recycled material in Lyme, which jumped from 89 tons in 2005 to 334 tons in 2006, included corrugated cardboard, which sold for $90 a ton, mixed paper at $45 a ton, and aluminum at $1,500 a ton. This program simultaneously reduced the town's landfill fees while generating a cash flow from the sale of recycled material.[85]

In addition to measures that encourage recycling, there are those that encourage or mandate the reuse of products such as beverage containers. Finland, for example, has banned the use of one-way soft drink containers. Canada's east coast province, Prince Edward Island, has adopted a similar ban on all nonrefillable beverage containers. The result in both cases is a sharply reduced flow of garbage to landfills. A refillable glass bottle used over and over requires about 10 percent as much energy per use as an aluminum can that is recycled. Cleaning, sterilizing, and relabeling a used bottle requires little energy compared with recycling cans made from aluminum, which has a melting point of 1,220 degrees Fahrenheit. Banning nonrefillables is a quintuple win option—cutting material use, carbon emissions, air pollution, water pollution, and landfill costs simultaneously. There are also substantial transport fuel savings, since the refillable containers are simply back-hauled by delivery trucks to the original bottling plants or breweries for refilling.[86]

San José, California, already diverting 62 percent of its municipal waste from landfills for reuse and recycling, is now focusing on the large flow of trash from construction and demolition sites. This material is trucked to one of two dozen specialist recycling firms in the city. For example, at Premier Recycle up to 300 tons of building debris are delivered each day. This is skillfully separated into recyclable piles of concrete, scrap metal, wood, and plastics. Some materials the company sells, some it gives away, and some it just pays someone to take.[87]

Before the program began, only about 100,000 tons per year of San José's mixed construction and demolition materials were reused or recycled. Now it is nearly 500,000 tons. The scrap metal that is salvaged goes to recycling plants, wood can be converted into gardening mulch or into wood chips for fueling power plants, and concrete can be recycled to build road banks. By deconstructing a building instead of simply demolishing it, most of the material in it can be reused or recycled, thus dramatically reducing energy use and carbon emissions. San José is becoming a model for cities everywhere.[88]

Germany and, more recently, Japan are requiring that products such as automobiles, household appliances, and office equipment be designed for easy disassembly and recycling. In May 1998, the Japanese Diet enacted a tough appliance recycling law, one that prohibits discarding household appliances, such as washing machines, TV sets, or air conditioners. With consumers bearing the cost of disassembling appliances in the form of a disposal fee to recycling firms, which can come to $60 for a refrigerator or $35 for a washing machine, there is strong pressure to design appliances so they can be more easily and cheaply disassembled.[89]

With computers becoming obsolete every few years as technology advances, the need to quickly disassemble and recycle them is another paramount challenge in building an eco-economy. In Europe, information technology (IT) firms are exploring the reuse of computer components. Because European law requires manufacturers to pay for the collection, disassembly, and recycling of toxic materials in IT equipment, they have begun to focus on how to disassemble everything from computers to cell phones. Finland-based Nokia, for example, has designed a cell phone that will virtually disassemble itself.[90]

On the clothing front, Patagonia, an outdoor gear retailer, has launched a garment recycling program beginning with its polyester fiber garments. Working with Teijin, a Japanese firm, Patagonia is taking back and recycling not only the polyester garments it sells but also those sold by its competitors. Patagonia estimates that making a garment from recycled polyester, which is indistinguishable from the initial polyester made from petroleum, uses less than one fourth as much energy. With this success behind it, Patagonia has broadened the program to recycle its cotton tee shirts as well as nylon and wool clothing.[91]

Remanufacturing is even more efficient. Within the heavy industry sector, Caterpillar has emerged as a leader. At a plant in Corinth, Mississippi, the company recycles some 17 truckloads of diesel engines a day. These engines, retrieved from Caterpillar's clients, are disassembled by hand by workers who do not throw away a single component, not even a bolt or screw. Once the engine is disassembled, it is reassembled with all worn parts repaired or replaced. The resulting engine is as good as new. In 2006, Caterpillar's remanufacturing division was racking up $1 billion a year in sales and growing at 15 percent annually, contributing impressively to the company's bottom line.[92]

Another emerging industry is airliner recycling. Daniel Michaels writes in the *Wall Street Journal* that Boeing and Airbus, which have been building jetliners in competition for nearly 40 years, are now vying to see who can dismantle planes most efficiently. The first step is to strip the plane of its marketable components, such as engines, landing gear, galley ovens, and hundreds of other items. For a jumbo jet, these key components can collectively sell for up to $4 million. Then comes the final dismantling and recycling of aluminum, copper, plastic, and other materials. The next time around the aluminum may show up in cars, bicycles, or another jetliner.[93]

The goal is to recycle 90 percent of the plane, and perhaps one day 95 percent or more. With more than 3,000 airliners already put out to pasture and many more to come, this retired fleet has become the equivalent of an aluminum mine.[94]

Another increasingly attractive option for cutting carbon emissions is to discourage energy-intensive but nonessential industries. The gold jewelry, bottled water, and plastic bag industries are prime examples. The annual world production of 2,380 tons of gold, the bulk of it used for jewelry, requires the processing of 500 million tons of ore. For comparison, while 1 ton of steel requires the processing of 2 tons of ore, 1 ton of gold involves processing an almost incomprehensible 200,000 tons of ore. Processing ore for gold consumes a vast amount of energy—and emits as much CO_2 as 5.5 million cars.[95]

In a world trying to stabilize climate, it is very difficult to justify bottling water (often tap water to begin with), hauling it over long distances, and then selling it for 1,000 times the price of tap water. Although clever marketing, designed to undermine public confidence in the safety and quality of municipal water supplies, has convinced many consumers that bottled water is safer and healthier than water from faucets, a detailed study by the World Wide Fund for Nature could not find any support for this claim. It notes that in the United States and Europe there are more standards regulating the quality of tap water than bottled water. For people in developing countries where water is unsafe, it is far cheaper to boil or filter water than to buy it in bottles.[96]

Manufacturing the nearly 28 billion plastic bottles used each year to package water in the United States alone requires the equivalent of 17 million barrels of oil. And whereas tap water is delivered through a highly energy-efficient infrastructure, bottled water is hauled by trucks, sometimes over hundreds of miles. Including the energy for hauling water from bottling plants to sales outlets and the energy needed for refrigeration, the U.S. bottled water industry consumes roughly 50 million barrels of oil per year, enough oil to fuel 3 million cars for one year.[97]

The good news is that people are beginning to see how wasteful and climate-disruptive this industry is. Mayors of U.S. cities are refusing to spend taxpayer dollars to buy bottled water for their employees at exorbitant prices when high-quality tap water is readily available. Mayor Rocky Anderson of Salt Lake City noted the "total absurdity and irresponsibility, both economic and environmental, of purchasing and using bottled water when we have perfectly good and safe sources of tap water."[98]

San Francisco Mayor Newsom has banned the use of city funds to purchase bottled water. Other cities following a similar strategy include Los Angeles, Salt Lake City, and St. Louis. New York City has launched a $5-million ad campaign to promote its tap water and thus to rid the city of bottled water and the fleets of delivery trucks that tie up traffic. In response to initiatives such as these, U.S. sales of bottled water began to decline in 2008.[99]

Like plastic water bottles, throwaway plastic shopping bags are also made from fossil fuels, can take centuries to decompose, and are almost always unnecessary. In addition to local initiatives, several national governments are moving to ban or severely restrict the use of plastic shopping bags, including China, Ireland, Eritrea, Tanzania, and the United Kingdom.[100]

In summary, there is a vast worldwide potential for cutting carbon emissions by reducing materials use. This begins with the major metals—steel, aluminum, and copper—where recycling requires only a fraction of the energy needed to produce these metals from virgin ore. It continues with the design of cars, household appliances, and electronic products so they are easily disassembled into their component parts for reuse or recycling. And it includes avoiding unnecessary products.

Smarter Grids, Appliances, and Consumers

More and more utilities are beginning to realize that building large power plants just to handle peak daily and seasonal demand is a very costly way of managing an electricity system. Existing electricity grids are typically a patchwork of local grids that are simultaneously inefficient, wasteful, and dysfunctional in that they often are unable, for example, to move electricity surpluses to areas of shortages. The U.S. electricity grid today resembles the roads and highways of the mid-twentieth century before the interstate highway system was built. What is needed today is the electricity equivalent of the interstate highway system.[101]

The inability to move low-cost electricity to consumers because of congestion on transmission lines brings with it costs similar to those associated with traffic congestion. The lack of transmission capacity in the eastern United States is estimated to cost consumers $16 billion a year in this region alone.[102]

In the United States, a strong national grid would permit power to be moved continuously from surplus to deficit regions, thus reducing the total generating capacity needed. Most important, the new grid would link regions rich in wind, solar, and geothermal energy with consumption centers. A national grid, drawing on a full range of renewable energy sources, would itself be a stabilizing factor.

Establishing strong national grids that can move electricity as needed and that link new energy sources with consumers is only half the battle, however. The grids and appliances need to become "smarter" as well. In the simplest terms, a smart grid is one that takes advantage of advances in information technology, integrating this technology into the electrical generating, delivery, and user system, enabling utilities to communicate directly with customers and, if the latter agree, with their household appliances.

Smart grid technologies can reduce power disruption and fluctuation that cost the U.S. economy close to $100 billion a year, according to the Electric Power Research Institute. In an excellent 2009 Center for American Progress study, *Wired for Progress 2.0: Building a National Clean-Energy Smart Grid*, Bracken Hendricks notes the vast potential for raising grid efficiency with several information technologies: "A case in point would be encouraging the widespread use of synchrophasors to monitor voltage and current in real time over the grid network. It has been estimated that better use of this sort of real-time information across the entire electrical grid could allow at least a 20 percent improvement in energy efficiency in the United States." This and many other examples give us a sense of the potential for increasing grid efficiency.[103]

A smart grid not only moves electricity more efficiently in geographic terms; it also enables electricity use to be shifted over time—for example, from periods of peak demand to those of off-peak demand. Achieving this goal means working with consumers who have "smart meters" to see exactly how much electricity is being used at any particular time. This facilitates two-way communication between utility and consumer so they can cooperate in reducing peak demand in a way that is advantageous to both. And it allows the use of two-way metering so that customers who have a rooftop solar electric panel or their own windmill can sell surplus electricity back to the utility.[104]

Smart meters coupled with smart appliances that can receive signals from the grid allow electricity use to be shifted away from peak demand. Higher electricity prices during high demand periods also prod consumers to change their behavior, thus improving market efficiency. For example, a dishwasher can be programmed to run not at 8 p.m. but at 3 a.m., when electricity demand is much lower, or air conditioners can be turned off for a brief period to lighten the demand load.[105]

Another approach being pioneered in Europe achieves the same goal but uses a different technology. In any grid, there is a narrow range of fluctuation in the power being carried. An Italian research team is testing refrigerators that can monitor the grid flow and, when demand rises or supply drops, simply turn themselves off for as long as it is safe to do so. *New Scientist* reports that if this technology were used in the 30 million refrigerators in the United Kingdom, it would reduce national peak demand by 2,000 megawatts of generating capacity, allowing the country to close four coal-fired power plants.[106]

A similar approach could be used for air conditioning systems in both residential and commercial buildings. Karl Lewis, COO of GridPoint, a U.S. company that designs smart grids, says "we can turn off a compressor in somebody's air conditioning system for 15 minutes and the temperature really won't change in the house." The bottom line with a smart grid is that a modest investment in information technology can reduce peak power, yielding both savings in electricity and an accompanying reduction in carbon emissions.[107]

Some utilities are pioneers in using time-based pricing of electricity, when electricity used during off-peak hours is priced much lower than that used during peak hours. Similarly, in regions with high summer temperatures, there is often a costly seasonal peak demand. Baltimore Gas and Electric (BGE), for example, conducted a pilot program in 2008 in which participating customers who permitted the utility to turn off their air conditioners for selected intervals during the hottest days were credited generously for the electricity they saved. The going rate in the region is roughly 14¢ per kilowatt-hour. But for a kilowatt-hour saved during peak hours on peak days, customers were paid up to $1.75—more than 12 times as much. Thus if they saved 4 kilowatt-hours of electricity in one afternoon, they got a $7 credit on their electricity bill. Customers reduced their peak electricity consumption by as much as one third, encouraging BGE to design a similar program with even more "smart" technology for summer 2009.[108]

Within the United States the shift to smart meters is moving fast, with some 28 utilities planning to deploy smart meters in the years ahead. Among the leaders are California's two major utilities, Pacific Gas and Electric and Southern California Edison, which are planning on full deployment to their 5.1 million and 5.3 million customers by 2012. Both will offer variable rates to reduce peak electricity use. Among the many other utilities aiming for full deployment are American Electric Power in the Midwest (5 million customers) and Florida Power and Light (4.4 million customers).[109]

Europe, too, is installing smart meters, with Finland setting the pace. A Swedish research firm, Berg Insight, projects that Europe will have 80 million smart meters installed by 2013.[110]

Unfortunately, the term "smart meters" describes a wide variety of meters, ranging from those that simply provide consumers with real-time data on electricity use to those that facilitate two-way communication between the utility and customer or even between the utility and individual household appliances. The bottom line: the smarter the meter, the greater the savings.[111]

Taking advantage of information technology to increase the efficiency of the grid, the delivery system, and the use of electricity at the same time is itself a smart move. Simply put, a smart grid combined with smart meters enables both electrical utilities and consumers to be much more efficient.

The Energy Savings Potential

The goal for this chapter was to identify energy-saving measures that will offset the nearly 30 percent growth in global energy demand projected by the IEA between 2006 and 2020. My colleagues and I are confident that the measures proposed will more than offset the projected growth in energy use.[112]

Shifting to more energy-efficient lighting alone lowers world electricity use by 12 percent. With appliances, the key to raising energy efficiency is to establish international efficiency standards that reflect the most efficient models on the market today, regularly raising this level as technologies advance. This would in effect be the global version of Japan's Top Runner program to raise appliance efficiency.

Given the potential for raising appliance efficiency, the energy saved by 2020 should at least match the savings in the lighting sector. Combining more-efficient lights and appliances with a smart grid that uses time-of-day pricing, peak demand sensors, and the many other technologies described in this chapter shows a huge potential for reducing both overall electricity use and peak demand.[113]

It is easy to underestimate the potential for reducing electricity use. Within the United States, the Rocky Mountain Institute calculates that if the 40 least efficient states were to achieve the electrical efficiency of the 10 most efficient ones, national electricity use would be cut by one third. This would allow the equivalent of 62 percent of all U.S. coal-fired power plants to be closed down. But even the most efficient states have a substantial potential for further reducing electricity use and, indeed, are planning to keep cutting carbon emissions and saving money.[114]

In terms of transportation, the short-term keys to reducing oil use and carbon emissions involve shifting to highly fuel-efficient cars (including electric vehicles), diversifying urban transport systems, and building intercity rapid rail systems modeled on those in Japan and Europe. This shift from car-dominated transport systems to diversified systems is evident in the actions of hundreds of mayors worldwide who struggle daily with traffic congestion and air pollution. They are devising ingenious ways of limiting not only the use of cars but also the very need for them. As the urban car presence diminishes, the nature of the city itself will change.

Within the industrial sector, there is a hefty potential for reducing energy use. In the petrochemical industry, moving to the most efficient production technologies now available and recycling more plastic can cut energy use by 32 percent. Gains in manufacturing efficiency in steel can cut energy use by 23 percent. Even larger gains are within reach for cement, where simply shifting to the most efficient dry kiln technologies can reduce energy use by 42 percent.[115]

With buildings—even older buildings, where retrofitting can reduce energy use by 20–50 percent—there is a profitable potential for saving energy. As noted earlier, such a reduction in energy use, combined with the use of renewable electricity to heat, cool, and light the building, means that it will be easier to create carbon-neutral buildings than we may have thought.

One simple way to achieve all these gains is to adopt a carbon tax that would help reflect the full cost of burning fossil fuels. We recommend increasing this carbon tax by $20 per ton each year over the next 10 years, for a total of $200 ($55 per ton of CO_2), offsetting it with a reduction in income taxes. High though this may seem, it does not come close to covering all the indirect costs of burning fossil fuels. It does, however, encourage investment in both efficiency and carbon-free sources of energy.

In seeking to raise energy efficiency as described in this chapter, there have been some exciting surprises in the vast potential for doing so. We now turn to developing the earth's renewable sources of energy, where there are equally exciting possibilities.