AMERICA'S ENERGY FUTURE

Real Prospects for Energy Efficiency in the United States

With an accelerated effort to employ a variety of efficiency technologies in the buildings, transportation, and industrial sectors, the United States by 2030 could reduce its energy use by 30 percent while saving money. This reduction would lower total U.S. energy use below the 1990 level. Most of these efficiency technologies are available today and deliver the same services as their less efficient counterparts, and many have already been demonstrated in other developed countries and some U.S. states.

America is the world's largest user of energy, and our energy consumption has doubled since 1963. In fact, most developed countries use far less energy per person and per dollar of gross domestic product (GDP) than the United States. Those countries' use of energy efficiency technologies accounts for about 50 percent of this difference. Even in the United States, energy efficiency improvements have contributed substantially to holding electricity use per capita in California and New York constant since 1980, even as this ratio expanded by 50 percent in the rest of the country. Expanding our use of these technologies can allow the United States to use less energy and maintain economic growth.

This report from the National Academy of Sciences and National Academy of Engineering examines a wide range of energy efficiency technologies in the buildings, transportation, and industry sectors that are available now or expected to be developed in the normal course of business in the next decade. Assuming consumers and businesses will adopt these technologies more quickly than they have previously, the report finds that America could reduce energy use by 17 to 22 percent by 2020 and 25 to 31 percent by 2030. In buildings alone, these technologies could eliminate the need to increase electric generating capacity, despite economic and population growth. Cost-effective energy improvements are the cheapest and quickest way to move toward a sustainable energy future with lower greenhouse gas emissions.

Efficiency Opportunities in Buildings

In 2006, buildings used 39 percent of America's primary energy and 72 percent of electricity. To calculate the potential of current and near-term efficiency technologies, the report's authoring committee examined a number of studies of various technologies and found consistent conclusions. They estimated it is possible, using cost-effective technologies, to achieve an annual reduction of 1.2 percent in electricity and 0.5 percent in natural gas use (see Figure 1).

Several technologies can help fulfill this potential. Advanced lighting measures, including light emitting diodes (LEDs) and compact fluorescent lamps, could save 35 percent of the electricity used for lighting in 2030. Using advanced technologies, the electricity used for cooling could be reduced by 36 percent in 2030. Right now, available technology integrated into a holistic building design could save up to

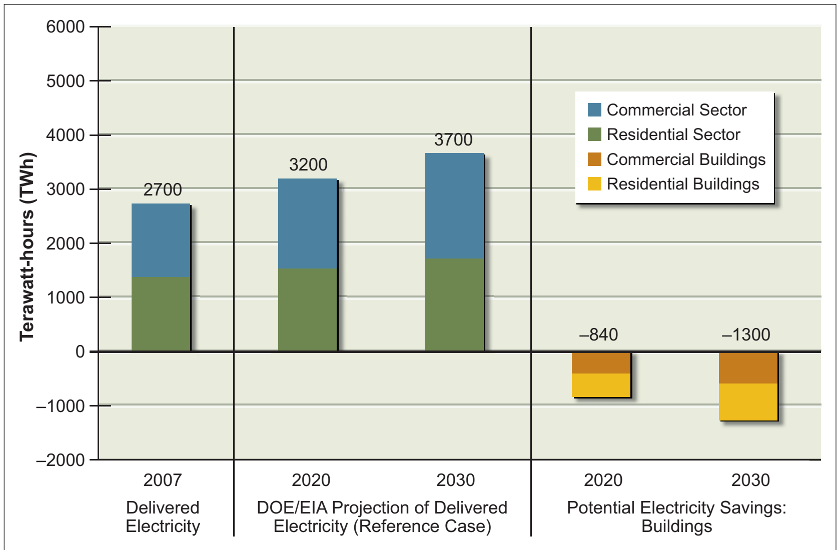

Figure 1: The 2007 U.S. delivered energy, used mainly in buildings, is on the left. The building sector's 2020 and 2030 projected electricity consumption without accelerated adoption of efficiency technologies is in the middle. The sector's potential savings with an accelerated adoption of efficiency technologies is on the right.

50 percent of the energy the building would otherwise use, while lowering lifetime cost.

However, many barriers stand in the way of achieving these improvements. There is often a mismatch between the person who invests in the technology and the one who benefits from it. Builders and landlords decide on energy efficiency investments but do not realize the savings since they do not pay energy bills. Even when an investor pays for the electricity, an energy efficiency investment might become worthless with volatile fuel prices. Risk averse investors prefer to pay a higher price for energy than commit to large efficiency investments.

Efficiency Opportunities in Transportation

Today, transportation relies almost completely on petroleum, using 28 percent of America's primary energy and producing 30 percent of its greenhouse gas emissions. Highway transportation alone (including all on-road vehicles but not other modes such as rail or air) accounts for 75 percent of the energy used in transportation.

Automakers have the ability to produce much more efficient vehicles. Although the efficiency of vehicle technology has improved steadily over the past 25 or so years, these improvements have been used to offset the fuel consumption impacts of shifting to larger, heavier, and more powerful vehicles. To meet new federal standards, automakers will need to apply at least 75 percent of future efficiency improvements to reducing fuel consumption directly. If they are able to maintain that rate of improvement past 2020, gasoline consumption is expected to level off and then decrease, despite a predicted increase in vehicle miles traveled.[1]

Through 2020, most of these improvements will be made by increasing the efficiency of existing gasoline, diesel, and hybrid-electric engines. As these are already on the market, incremental advances in them have a larger immediate impact than the introduction of substantially new technologies that will have a small initial market share (see Table 1). Advances in the gasoline-fueled spark-ignition engine, the most common type, could reduce an average vehicle's fuel consumption 10 to 15 percent by 2020. When combined with reductions in vehicle weight, drag, and tire rolling resistance, a vehicle with the same size and performance as today's conventional vehicles could use 35 percent less fuel by 2035. At the same time, hybrid engines (now 3 percent of the market) which are already up to 30 percent more efficient, will probably become less expensive relative to conventional vehicles. However, plug-in hybrid electric and battery electric vehicles are unlikely to enter the fleet in large numbers before 2020. Similarly, given the current state of fuel cell technology and of hydrogen storage onboard vehicles, and in view of the time, expense, and technical difficulty of establishing a nationwide hydrogen distribution system, the report concludes that fuel cell vehicles are unlikely to comprise a large proportion of the light duty fleet for several decades. Small numbers of vehicles may join the fleet in the middle of the next decade in particular cities in response to regulations and technology advocates. As with all the advanced

Table 1. Plausible Shares of Advanced Light-Duty Vehicles in the New-Vehicle Market by 2020 and 2035

	Plausible LDV Market Share by	
Propulsion System	**2020**	**2035**
Turbocharged Gasoline SI	15-25%	25-35%
Gasoline Hybrids	10-15%	15-40%
Diesels	6-12%	10-20%
Plug-in Hybrids	1-3%	7-15%
Battery Electric Vehicles	0-2%	3-10%
Hydrogen Fuel Cell Vehicles	0-1%	3-6%

[1] This report was based on standards that were meant to be implemented in 2020. However, the Obama administration has reached an agreement to accelerate their implementation to 2016.

technologies, the market share of the fuel cell vehicle will result from competition among fuel types, regulations, performance, and technological progress.

In addition, consumer preferences for convenience, style, and power may limit improvements in fuel economy. The inability of vehicle manufacturers to rapidly and drastically change the production process may also restrict the rate of change.

America spends 6 to 7 percent of its gross domestic product on freight transportation, nearly all of which is done by truck. Trucking companies could immediately improve fuel economy by 1 to 2 miles per gallon by improving engine maintenance, enhancing aerodynamics, and limiting driving speed. Moving freight from truck to rail would also save energy, as rail is ten times more efficient.

The efficiency of air travel, which is used for both passenger and freight transport, is expected to increase by 1 to 2 percent annually. However, these advances are not expected to offset the predicted increase in energy use from growth in air travel.

Efficiency Opportunities in Industry

Industry uses 33 percent of America's primary energy and produces 28 percent of its CO_2 emissions. It is currently expected that industry's energy use will grow by 0.3 percent annually and greenhouse gas emissions by 0.2 percent. However, the potential to increase efficiency is huge—the sector could reduce energy use by 14 to 22 percent by 2020 by using financially attractive technologies (see Figure 2).

The chemical and petroleum sectors are two of the top five most energy-intensive industries; the average plant spends 20 percent of its production costs on energy. The chemical industry has the potential to reduce 3 to 18 percent of its energy use by 2020. Petroleum has even more capacity, as most refineries could cut their energy use now by 10 to 20 percent. By 2020, studies predict the sector has the potential to reduce its use by 5 to 54 percent, with the largest savings from modifications to the distillation process.

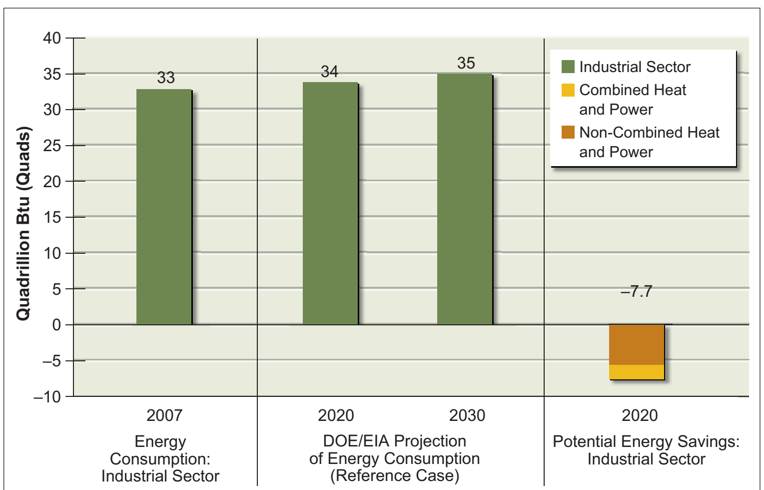

Figure 2: The 2007 U.S. delivered energy to the industrial sector is the left-most bar. The industrial sector's projected energy consumption in 2020 and 2030 without accelerated adoption are the two middle bars. The sector's potential savings with accelerated adoption of efficiency technologies is the right-most bar.

Cement production, which worldwide generates 5 percent of global human-produced CO_2 emissions, could also achieve significant efficiency gains. During the most energy-intensive part of the process, when limestone is converted to lime, U.S. producers use 80 percent more energy than their Japanese counterparts. As this process's main chemical reaction also produces greenhouse gases, reducing the amount of lime in cement would significantly reduce the sector's emissions. The biggest improvement, which requires upgrading a factory's kiln, is economical only when producers must replace an old kiln. However, using affordable measures, producers could reduce energy use by 19 to 21 percent now and potentially up to 32 percent by 2020. In addition, upgrading building codes to allow the use of cement with a lower percent of limes would further reduce energy use.

In the iron and steel industries, the American Iron and Steel Institute announced a goal of using 40 percent less energy per ton of steel in 2025 than was used in 2003. The most promising opportunities include advances in melting, heat recovery, and heat capture from waste gas. The committee estimates that by 2025, the industry has the potential to reduce its energy use between 15 and 58 percent.

Of the many technologies that can be used across industrial applications, combined heat and power has the most energy-saving potential. This process uses the waste heat that is produced when fuel is converted to electricity for water heating, space heating, or industrial processes. Although burning fuel for electricity is only 30 percent efficient, combined heat and power can be 50 to 80 percent efficient. For installations that use large amounts of electricity and natural gas, it can double efficiency and cut energy costs by up to half.

Improving energy efficiency in industry faces significant barriers. Even when energy efficient technologies are more dependable than ever, cautious business owners are often concerned about the reliability of any new technology, regardless of its application. There is also a lack of industry-specific knowledge about these specialized technologies. Fiscal policies can also deter upgrades, particularly laws and regulations that require companies to depreciate energy efficiency investments over years when energy is a current expense. Changing these laws would remove a major barrier to industrial efficiency investments. Despite these barriers, environmental regulations, international competition, corporate sustainability efforts, and liability concerns may help encourage adoption of these technologies.

Lessons Learned

Some national and state policies have already started the United States on the path to fulfilling the energy efficiency's potential. Separate national fuel economy standards for automobiles and light trucks enacted in 1975 resulted in a near doubling of the fleet's fuel economy between 1974 and 1988. Although light truck fuel economy standards were increased several years ago, automobile standards were fixed until 2007. New standards were recently adopted that require a 40 percent combined increase in fuel economy for automobiles and light trucks by 2020. In May 2009, the Obama Administration came to an agreement with the automotive industry and the State of California to accelerate compliance with these standards to 2016. Full implementation of these requirements, whether achieved through efficiency technology improvements that advance rapidly enough alone, reductions in vehicle weight and power, or accumulating regulatory credits for flexible fuel or electric vehicles, could save one million barrels of oil a day. Appliance efficiency standards, which remove the least efficient products from the market, lowered the nation's electricity use by 2.5 percent in 2000 and should lower it another 6.9 percent by 2010. Laws that encourage industry to adopt combined heat and power technology saved 1.62 quads of power in 2006, or about 5.2 percent of industry's energy use. State and utility efficiency programs saved 2 percent of electricity nationally and up to 9 percent in some states. In total, these efforts have reduced national energy use by 13 percent, more than the energy produced by nuclear and hydroelectric power combined.

However, energy prices pose one of the biggest barriers to investing in energy efficiency technologies. They do not reflect environmental and health costs and can be unpredictable. People do not want to invest in efficiency measures if they are not certain they will save money in the long run. In addition, long-lived capital stock, such as buildings and appliances, can "lock in" patterns of energy use for decades. Therefore, it is important to encourage people when they are making a major investment, such as buying a house or new piece of industrial equipment, to consider their long-term energy costs and adopt these technologies.

Panel on Energy Efficiency Technologies: Lester B. Lave (*Chair*), Carnegie Mellon University; **Maxine L. Savitz** (*Vice Chair*), Honeywell Inc. [Retired]; **Paul A. DeCotis**, State of New York, Office of the Governor; **R. Stephen Berry**, The University of Chicago; **Marilyn A. Brown**, Georgia Institute of Technology; **Linda R. Cohen**, University of California, Irvine; **Magnus G. Craford**, LumiLeds Lighting; **James DeGraffenreidt**, **Jr.**, WGL Holdings, Inc.; **Howard Geller**, Southwest Energy Efficiency Project; **David B. Goldstein**, Natural Resources Defense Council; **Alexander MacLachlan**, E. I. du Pont de Nemours & Company [Retired]; **William F. Powers**, Ford Motor Company [Retired]; **Arthur H. Rosenfeld**, E. O. Lawrence Berkeley National Laboratory; **Daniel Sperling**, University of California, Davis; **John Heywood**, Massachusetts Institute of Technology; **Madeline Woodruff** (*Study Director, 2007-September, 2009*) **Gregory Eyring** (*Study Director, September, 2009-December 2009*) **James Zucchetto** (*Project Manager, America's Energy Future Project*) **Peter D. Blair** (*Project Director, America's Energy Future Project*), National Research Council.

This report brief was prepared by the National Research Council (NRC) based on the committee's report. The NRC appointed the above panel of experts, who volunteered their time for this activity. The NRC study was initiated by the National Academy of Sciences and the National Academy of Engineering and subsequently endorsed by a request from Congress. The committee's report is peer-reviewed and signed off by both the committee members and the NRC.

EXPERT CONSENSUS REPORT

For more information on this report or the America's Energy Future initiative, contact the Board on Energy and Environmental Systems at (202) 334-3344 or visit http://nationalacademies.org/energy. Copies of *Realistic Prospects for Energy Efficiency in the United States* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.