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COMPANY LISTING

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Boosting Prosperity:

Reducing the Threat of Global Climate Change Through Sustainable Energy Investments

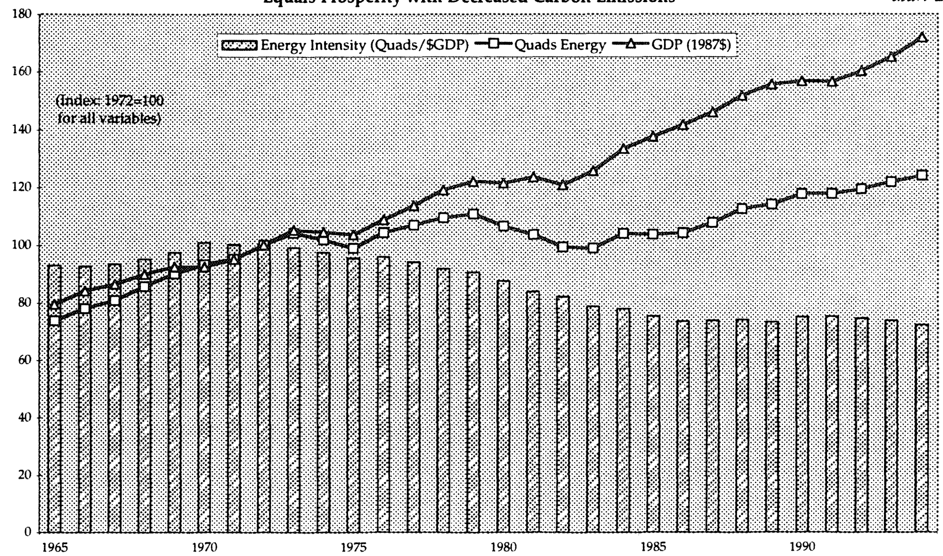
THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), an international group of 2,500 climate scientists assembled under the authority of the United Nations to monitor global climate, recently documented the causal link between human activity and global climate change. The IPCC report declares that the 6 billion metric tons of carbon emitted into the atmosphere globally each year are indeed heating the planet. Because economic growth and energy consumption have historically marched in lockstep, there is great concern that policy measures aimed at reducing fossil-fuel use could constrain future prosperity.

Fortunately, the world need not choose between catastrophic climate change and economic growth. A host of new technologies offers the means to simultaneously boost the economy and reduce greenhouse gas emissions. U.S. businesses, municipalities, and educational institutions are finding that investments in energy efficiency cut power bills and provide a rapid payback, while reducing carbon dioxide emissions. So while some argue that cutting U.S. carbon dioxide emissions would be a costly drag on the economy,[1] this report shows dozens of examples of how carbon dioxide reductions are often a beneficial side effect of profitable, energy-saving business choices.

Energy efficiency[2] can increase profitability and competitiveness by lowering the cost of doing business. When businesses improve their manufacturing processes to use energy and raw materials more efficiently, carbon dioxide emissions and environmental compliance costs fall while profitability, productivity, and competitiveness improve, creating jobs.

A. Energy Efficiency and Renewable Energy Reduce the Threat of Global Climate Change While Fueling Economic Growth

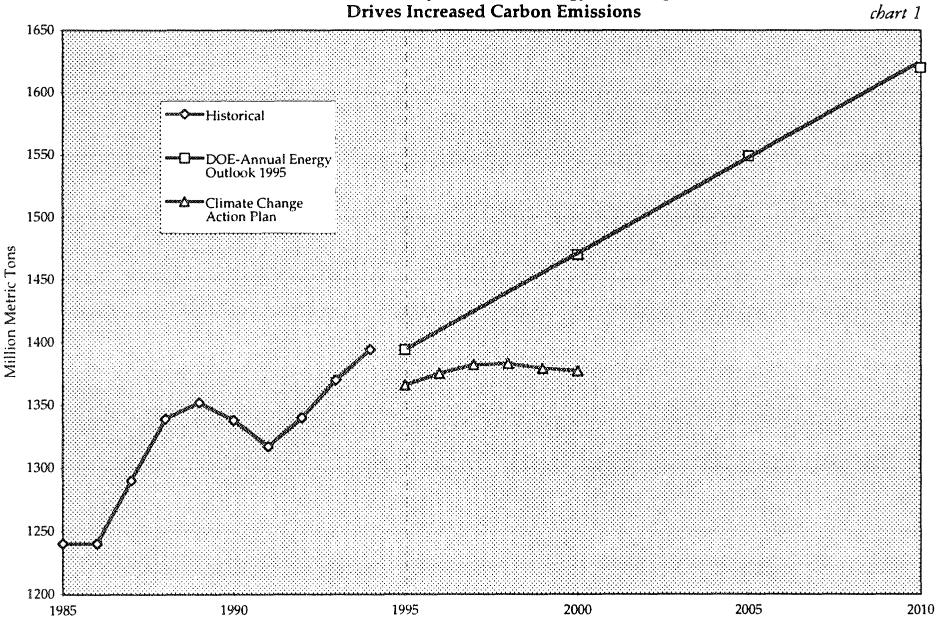
**Energy Efficiency:
Decoupling Economic Growth from Energy Consumption
Equals Prosperity with Decreased Carbon Emissions** *chart 2*



Source: U.S. Department of Energy (DOE), Energy Information Administration

Energy-related carbon emissions in the United States have reached an all-time high. Emissions resulting from the nation's use of fossil fuels climbed to 1,394 million metric tons in 1994, an increase of 24 million metric tons (1.8 percent) over 1993 levels, and of 56 million metric tons (4.2 percent) compared with 1990 levels.[3] But this growth in carbon emissions can be reversed. A national energy strategy that emphasizes energy efficiency and renewable energy could remedy the threat posed by global climate change.

**Carbon Emission Trends:
Without Efficiency, Increased Energy Consumption
Drives Increased Carbon Emissions** *chart 1*



Source: DOE, American Council for an Energy-Efficient Economy

Numerous studies have examined the impact of a national energy strategy that emphasizes greater energy efficiency. *America's Energy Choices*,[4] for example, showed that vigorous adoption of cost-effective energy efficiency and renewable energy measures could cut national energy usage in 2030 by nearly 50 percent. Those same measures could dramatically reduce our nation's petroleum dependence, save consumers more than $2 trillion net over the next 40 years, and cut carbon dioxide emissions in 2030 by more than 70 percent (relative to emissions in 1988).[5] The Electric Power Research Institute (EPRI) estimates that 23 percent of all U.S. electricity consumption could be saved for less than 3 cents per kilowatt-hour—which is less than the cost of generating that electricity.[6]

B. Energy Efficiency Does Not Mean Reduced Economic Growth

Prior to 1973, U.S. energy consumption and the Gross National Product (GNP) seemed to be inexorably linked. But more recent history shows that energy consumption can be reduced during economic expansion. From 1973 to 1986, GNP grew 35 percent while the energy consumed per unit of GDP *fell* to 2.4 percent per year. Some 26.6 "quads"[7] of anticipated energy usage per year, worth $150 billion, never materialized—mostly due to improved energy efficiency.[8] A 50 percent increase in carbon dioxide emissions was thus avoided during this period.

The United States now uses about 85 quads of primary energy annually, resulting in a national energy bill of $505 billion per year.[9] The U.S.

Department of Energy (DOE) projects that with current trends and policies, energy use will increase to about 104 quads per year by 2010. Given this rise in demand and resultant increases in prices, our national energy bill in 2010 is projected to reach about $950 billion.[10] Increasing energy use creates a host of problems besides higher dollar outlays, including greater oil imports (DOE forecasts a 68 percent increase between 1990 and 2010) and greater pollutant emissions (DOE forecasts an 17 percent increase in carbon emissions between 1993 and 2010).[11]

Vigorous energy-efficiency improvements could lower consumers' energy bills and reduce the cost of energy services, cut oil imports, reduce pollutant emissions, create a net increase in jobs, *and* boost individual incomes.

C. Energy Efficiency and Renewables Markets Are Rapidly Growing, and Creating Jobs

Energy-efficiency and renewables-technology markets are growing rapidly and generating thousands of jobs nationwide. The American Council for an Energy-Efficient Economy (ACEEE) estimates that efficiency improvements consistent with a 2.4 percent annual reduction in national energy usage (the rate achieved in the U.S. during 1973-1986) could create a net increase of nearly 500,000 jobs by the year 2000 and nearly 1.1 million new jobs by 2010.[12]

A recent study has found that in Ohio alone as many as 63,000 jobs could be created by the year 2010 through energy-efficiency investments and the manufacture of energy-efficiency products.[13] For example, new jobs have been created at ***Staber Industries*** in Groveport, Ohio, which makes energy-saving clothes washers, and at ***General Electric*** in Circleville, Ohio, which makes compact fluorescent light bulbs. The majority of new jobs nationwide would be created as money saved on power bills is recirculated into the economy and spent on additional products and services.[14]

Current energy efficiency markets are already sizable. The global energy efficiency market is now in excess of $80 billion per year, and is projected to reach $115-140 billion annually by 2015.[15] Energy efficiency and environmental technology markets are large and growing all over the world.[16]

D. Successes Demonstrate That Cutting Carbon Dioxide Emissions Can Add to U.S. Prosperity

This report documents how U.S. businesses and individuals are increasing their bottom lines while improving economic prosperity, employment, and public health—and cutting greenhouse emissions.

- **Chapter I** reviews energy-efficiency success stories in the industrial sector, stories that demonstrate how companies that set out to cut electricity bills also improved worker productivity and became more competitive.
- **Chapter II** assesses a wide array of energy-saving electric utility programs and federal energy-efficiency programs that have saved the U.S. economy billions of dollars.
- **Chapter III** reviews gains in the energy-efficient design of commercial buildings and residences nationwide, and assesses ongoing innovations that could lead to improved building codes. It discusses commercial and residential energy-efficiency retrofit successes—including lighting upgrades—as well as efficiency gains in the design of appliances and equipment.
- **Chapter IV** reviews the transportation sector and the improvement in fuel efficiency over the last 20 years. It goes on to discuss how new automobile engines that are now available could double vehicle fuel efficiency, while electric and hybrid-electric vehicles—given incentives that would spur market development—could usher in a new age of clean transportation, powered by renewables-derived electricity.
- **Chapter V** reviews recent successes in renewable energy, including a drop in the cost per kilowatt-hour of wind, photovoltaic, solar thermal, and geothermal power. Wind can now compete head-to-head with fossil fuels.

All of the successes reviewed in this report not only save dollars and add to U.S. economic strength, but also cut carbon dioxide emissions and reduce the threat of global climate change. Our nation can grow economically, add jobs, and become more internationally competitive while cutting greenhouse gas emissions.

The task ahead is not simple, however. While the market has captured many efficiency and renewable energy successes, a host of market barriers to efficiency investments persists. For example, although efficiency and renewable energy technologies are often cheaper on a life-cycle basis, their up-front costs are typically higher than less-efficient products. Public policies that provide consumers with life-cycle product information could help overcome this market failure. Similarly, because it takes up-front capital to invest in improved efficiency, public policies that promote financing and technical assistance can facilitate investment. Although the focus of this report is on efficiency and renewable energy success stories, given the market hurdles to efficiency investments, utility efficiency programs and public policy incentives are crucial to encourage energy efficiency. The effects of tighter environmental regulations and the prospect of higher energy prices will increasingly make efficiency investments a prudent pursuit for all businesses.

Michael Porter, a professor at the Harvard Business School, notes that "the underlying cause of sustained national advantage is improvement and innovation."[17] The following case studies—coupled with the solid economic, employment, public health and pollution-reduction benefits reviewed in each—establish the need for a strategic vision for U.S. energy policy: energy efficiency and renewable energy can add to U.S. prosperity while cutting U.S. carbon dioxide emissions, reducing the threat of global climate change.

I. Industrial Energy Efficiency Successes

U.S. industries spend $121 billion per year on energy, consuming about a quarter of all U.S. energy.[18] While manufacturers account for roughly half of that annual bill ($61.1 billion in 1991), they are responsible for 85 percent of U.S. industrial carbon dioxide emissions—approximately 504 million metric tons annually. Efficiency improvements in the manufacturing process can reduce these emissions, cut consumption, and improve a company's bottom line.[19]

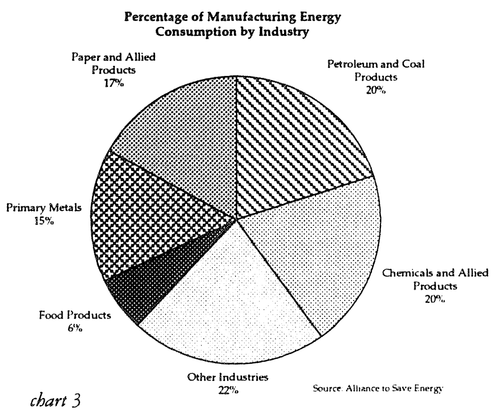


chart 3

According to several studies, the annual energy savings that could be attained by U.S. industry over the next two decades ranges from 11 to 27 percent of the demand that would otherwise occur, and potential savings by 2015 may reach as high as 38 percent.[20] These improvements depend, however, on the design and implementation of new policies and programs to stimulate more energy efficiency. Finding ways to encourage the installation of technologies such as high-efficiency motors,[21] computerized controls, industry-specific technologies, and cogeneration units could result in avoided energy consumption of 59 quads a year by 2010—a savings worth $183 billion in 1994 dollars.[22]

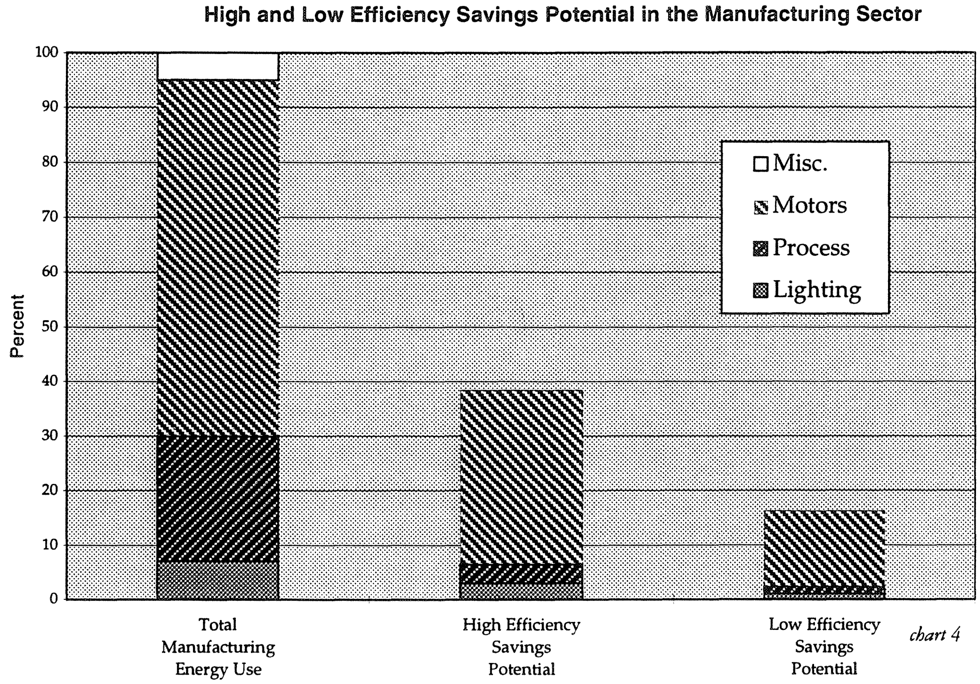


chart 4

Source: American Council for an Energy-Efficient Economy

A. Energy-Efficiency Investments Can Boost Productivity While Reducing Industrial Waste Materials

Inefficient industrial energy use is closely related to the generation of industrial waste materials. Industry is responsible for producing more than 544 million metric tons of hazardous wastes and approximately 11.8 billion metric tons of solid wastes each year.[23] Industry spends approximately $45 billion each year to meet emissions control requirements.[24] Minimizing the generation of waste materials, and transforming wastes into feedstocks, could reduce the nation's primary energy requirement by as much as 6 quads per year.[25] Energy efficiency technologies and processes, when installed "pre-end-of-the-pipe," can prevent pollution before it occurs, lowering production costs and thereby freeing capital for more productive purposes.

Both energy use and pollution are *controllable* costs. Although energy is typically a small percentage of total production costs,[26] other production costs—such as wages, work rules, materials costs, and disposal charges—are often more difficult to control. Controlling energy and waste cuts the operating budget and can have an enormous impact on a company's bottom line.[27] In many cases, the energy savings embodied in new technologies capable of reducing environmental emissions is sufficient to pay for upgrades—regardless of such other benefits as improved product quality or productivity. Energy efficiency should be a fundamental component of all manufacturers' environmental programs—to help them meet today's environmental regulations and tomorrow's more stringent standards.[28]

- ***3M Corporation.*** Often cited as one of the best-run companies in the world, 3M—based in St. Paul, Minnesota—has reduced its energy use per unit of production by one-half over the last 20 years, and in the process has reduced overall emissions by one-third. The company has achieved greater returns through energy-efficiency improvements than through alternative cost-cutting measures, and has pledged to implement all energy-saving projects with a 15 percent or greater return on investment (a payback period of six to seven years). It has aggressively pursued a corporate goal to further cut energy use per unit of production and per square foot of building space by 20 percent from 1990 through 1995.[29] Energy cost-cutting has made the company both more competitive and productive.

3M is also marketing a new "dual cure coating" process, a low-solvent technique that uses light to cure coatings. It is used for aircraft topcoats and primers, and for coatings for the backing of high-temperature electrical tape. The process produces superior physical properties with minimal volatile organic compound (VOC) emissions.[30] Based on a conservative projection of 10 percent market penetration, the new coatings could eliminate an estimated 236,000 metric tons of VOCs annually—7.5 percent of the U.S. total. This energy-efficient process will also reduce carbon dioxide emissions by an estimated 2 million metric tons a year. By the year 2010, 3M's new coatings could save an estimated 25 trillion Btu of energy—more than all the electricity used in all the commercial establishments in the state of Iowa in 1995.[31]

- ***Haskell-Lemon Construction Company.*** Haskell-Lemon Construction Company of Oklahoma City, Oklahoma manufactures asphalt paving products. Mixing hot asphalt can waste, in the form of exhaust steam, as much as 60 percent of the energy used in various stages of the mixing process. In 1989, Haskell-Lemon installed a heat-recovery system at one of three asphalt hot-mix plants to recover the waste steam, speed the manufacturing process, and reduce energy costs.

Haskell-Lemon personnel tested the system for two months and documented the energy savings. The new system reduced fuel requirements by 30 percent and increased production by as much as 40 percent. Emissions decreased by 50 percent because some toxic fumes that previously escaped with evaporating steam were condensed in the heat-recovery process. The heat-recovery system cost $100,000. Annual energy savings ranged between $20,000 and $30,000, depending on the cost of fuel, and thus the internal rate of return on the heat-recovery system was 20 to 33 percent.[32]

If all 4,500 hot-mix plants in the United States used the same heat-recovery process as Haskell-Lemon, the industry could save $250 million in energy costs each year. In 1991, the Haskell-Lemon project was selected for the DOE's Sixth National Awards Program for Energy Innovation.[33]

DOE's Energy Analysis and Diagnostic Center/Industrial Assessment Center (EADC/IAC) has issued several energy-saving recommendations for companies that mix asphalt paving. By installing the six most frequently recommended efficiency improvements,[34] each asphalt mixing company would spend an average of $54,393 and save $37,186 annually in reduced energy bills—while cutting carbon dioxide emissions each year by 652 metric tons.[35]

- ***Hill-Rom Company.*** Hill-Rom Company of Batesville, Indiana manufactures furniture and medical equipment. To address high energy costs in the mid-1980s, as well as a number of engineering problems, Hill-Rom installed a monitoring system for production equipment and an integrated maintenance control center. It saved $180,000 in energy costs by replacing inefficient space heaters with new high-efficiency heaters, installing a lighting control system, replacing manual motor starters on the ventilation system, and replacing manual heating, ventilation, and air conditioning (HVAC) controls with direct networked controls.[36]

The new monitoring systems improved productivity. The plant has been able to shorten maintenance response time, reduce machine downtime, and improve plant environmental conditions. The labor and material savings attributable to the systems amounted to $430,000 in 1990. Taken together, the direct energy savings and productivity savings enabled Hill-Rom to pay back its $424,300 investment in fewer than eight months.[37]

In Hill-Rom's industry, the DOE's EADC/IAC program audited 12 smaller-sized furniture manufacturing plants. The program identified 68 energy-saving measures.[38] The average cost of implementing the six most common recommendations was $3,770 per plant, and they yielded an average annual energy savings of $5,459 while cutting annual carbon dioxide emissions by 69 metric tons.[39]

• ***Brush Wellman, Inc.*** In 1991, perchloroethylene (PCE) spilled from a storage tank at Brush Wellman, Inc.'s facility in Elmore, Ohio. The spill contaminated groundwater and surrounding soils. Brush Wellman, a manufacturer of beryllium and beryllium alloy products, had relied on PCE as a cleaning solvent. But faced with a $1.49 million clean-up tab, the company set out to end the threat of spills and find alternatives to PCE cleaning systems.[40]

Brush Wellman's solution was to install a high-energy, dense-fluid cleaning system that uses nonhazardous (when not emitted as a greenhouse gas) carbon dioxide. The new cleaning process saved energy when compared with the previous system. Natural gas savings amounted to 31.66 million cubic feet per year, and electricity savings were 323 megawatt-hours annually.[41] The entire PCE waste stream was eliminated. All told, the new system cost $1.23 million while saving $282,000 per year in the costs of PCE solvent, steam, electricity, water, waste disposal, and maintenance. The payback period was just over 4 years. The new cleaning process has many potential applications: any metal-machining or product-processing company could adapt the system.[42] Besides the substantial annual energy savings, Brush Wellman's new cleaning system reduces overall carbon dioxide emissions from avoided electricity usage by 1,640 metric tons each year.[43]

• ***Chrysler Corporation.*** U.S. automobile manufacturers are seeking better paint-application systems to replace liquid spray-paint systems, which are major sources of VOC emissions. Chrysler Corporation's Newark, New Jersey assembly plant generates more than 83 metric tons of VOCs per year. Chrysler is developing powder coatings that could eventually replace liquid spray-paint systems in automobile manufacturing. Chrysler is installing and testing a full-body powder-paint antichip system[44] at its Newark facility.[45] The new system will save 24.3 billion Btu of energy per year by eliminating the old system's incinerator for the VOCs, and an additional 22.2 billion Btu per year by lowering the paint booth air heating requirements. The system virtually eliminates VOCs and nitrogen oxides emissions, and cuts carbon dioxide emissions by 2,951 metric tons annually. The system also uses paint more efficiently, eliminating 95 percent of the sludge waste that had to be landfilled under the old spray-paint system. Chrysler will save nearly $4 million per year from reduced material use, energy consumption, and waste disposal. This savings, combined with the superior performance of the powder-painted surfaces, could enhance the competitiveness of U.S. automotive manufacturers.[46]

B. Energy-Efficiency Investments Can Improve Competitiveness

The relatively low industrial energy prices in the United States are considered key competitive advantages in the global marketplace. However, these low prices also mean that U.S. manufacturers may place less importance on energy efficiency than do their competitors in Europe and Japan. This difference is illustrated in the selling prices of many products; one expert estimates that 5 percent of the difference in price between similar Japanese and American products is the result of more efficient energy use in Japanese plants.[47] U.S. industry can use energy efficiency to its competitive advantage.

• ***The Breyers Company.*** In New England, public utilities have helped local businesses and industries compete and expand by investing more than $500 million in energy efficiency since 1987. The efficiency expenditures have lowered the energy bills of these companies, and have benefited the utilities by delaying the need to build expensive new generation plants.[48] When the Breyers Company ice cream plant in Framingham, Massachusetts was having difficulty staying competitive, ***Boston Edison,*** the local utility, helped it install energy-efficiency improvements. The joint investment in energy-efficient refrigeration, heat-recovery systems, motors, and lighting reduced the plant's electricity use by 12.5 million kilowatt-hours (enough to power 2,000 homes) while simultaneously improving product quality and adding new jobs.[49] The electricity savings cut annual carbon dioxide emissions by more than 8,275 metric tons.[50]

• ***Big Bear Stores.*** The Big Bear Stores grocery chain in Ohio and West Virginia has aggressively cut electricity bills by installing computer-controlled refrigeration and freezer display cases, lighting, and ventilation systems. Waste heat from the refrigeration units helps heat both the stores and hot water. Freezers, refrigerated display cases, and air-conditioning systems all use high-efficiency motors and compressors. Company-wide, electrical costs per square foot have decreased by approximately 15 percent, saving the company $1 million per year and helping it price its foods more competitively.[51]

• ***Mar-Jac, Inc.*** Mar-Jac, Inc. is a poultry processor in Gainesville, Georgia that employs 550 people. Processing poultry requires water heated to between 120° and 130° F. The company used three natural gas-fired boilers to supply steam to the heat exchangers that heated the water. The boilers' low efficiency resulted in high energy costs, and maintenance was difficult and expensive.[52]

In 1988, the plant manager replaced the three steam boilers with two new water heaters capable of supplying water at up to 180° F, and installed a new direct-fired gas water heater as well. Both process improvements resulted in substantial energy savings. The new system cost $210,000, but reduced gas consumption by 40 percent—resulting in a payback of less than 3 years. The process manufacturing investments improved safety, reduced the possibility of blowing a boiler, and lowered maintenance costs while cutting emissions.[53]

The DOE's EADC/IAC conducts free energy audits at small- and medium-sized manufacturing plants around the country. These audits have resulted in an estimated energy savings of $517 million (94 trillion Btu), at a total cost to taxpayers of $27 million. EADC/IAC has issued energy-saving recommendations for various businesses, including poultry processors. By installing even the six most recommended efficiency improvements, each poultry processor would spend an average of $7,912 while saving $13,495 annually in reduced energy bills—and cutting carbon dioxide emissions each year by 304 metric tons.[54]

• ***Chris Erhart Foundry and Machine Company.*** Erhart Foundry in Cincinnati, Ohio produces iron castings for customers throughout the Midwest. The foundry has been in business for 140 years, but since the 1980s, the plant's effort to improve energy efficiency has been a "constant battle," says Dan Erhart. Energy comprises 15 to 20 percent of total operating costs, and any reduction in consumption goes to improving the company's competitive position in the industry.[55]

In the early 1990s, Erhart called in ***Cincinnati Gas & Electric*** (CG&E) for an energy audit. Based on CG&E recommendations, Erhart replaced the foundry's 500 incandescent fixtures with high pressure sodium fixtures that provided twice as much light while using a third less energy.[56]

Erhart's biggest investment, however, was a change in its foundry process. The company installed a computer controller on its 800-kilowatt induction furnace. Employees had been manually monitoring the furnace temperature, which made it extremely difficult to control demand. The controller is now reducing energy bills by 182 kilowatts per month—a 23 percent reduction—which saves $22,000 a year. The computer, which allows operation during off-peak hours and reduces the load during on-peak hours, paid for itself in six months. The energy savings shave 4 percent off Erhart's operating costs—a boon to productivity and competitiveness.[57]

C. Energy-Efficiency Investments Can Create Jobs

Energy efficiency cuts costs, increases productivity, and reduces pollution—while saving and often creating jobs. Implementing efficiency measures that are cost effective on a life-cycle basis leads to more jobs, higher personal incomes, and a higher GDP for the United States.[58] A number of case studies demonstrate how companies have benefited economically—and in some cases have even been turned around, by investing in energy efficiency.

• ***The Southwire Company.*** The Southwire Company, headquartered at Carrollton, Georgia, is a large manufacturer of copper rod, cable and wire. Southwire had soaring energy costs in the early 1980s, when its energy bills reached 20 percent of overhead and were rising. Profit margins were dropping, and the company had to lay off 1,000 of its 4,000 workers.[59]

Between 1981 and 1988, however, a comprehensive efficiency program saved Southwire $40 million in energy costs. Efficiency measures included a particularly successful motor efficiency program. The program focused on the life-cycle costs of motors, comparing the costs of rewinding older motors with the costs of buying new, high-efficiency motors. Southwire purchased high-efficiency motors whenever the net present value of the energy savings over five years exceeded the financing costs. To minimize downtime, the company then stocked the motors in preparation for their replacement. In addition, plant operators shut off many motors during peak demand times to avoid excess energy costs. The $40 million in energy savings cut overhead from 20 to 13 percent and turned Southwire into a profitable company.[60]

• *The Kelly Company.* As a leading manufacturer of injection molded and structural foam parts for the paint and hardware industries, The Kelly Company of Clinton, Massachusetts was a productive and profitable player in its industry for many years. But in the mid-1980s, the national recession and international competition brought the manufacturer to the brink of financial disaster and jeopardized the livelihoods of its 65 employees.[61]

Seeking to cut costs without cutting jobs, the company focused on reducing electricity costs, its third largest operating expense. With the assistance of ***Massachusetts Electric Company*** and the Massachusetts Industrial Services Program, Kelly installed variable-speed drives on injection molding machines, process cooling system improvements that included new high-efficiency pumps, and premium efficient grinders to reuse waste material generated by the injection molding machines. Kelly's electricity costs dropped 20 percent, saving $83,000 per year and enabling the company to expand product lines and add personnel. The efficiency improvements cut sulfur dioxide emissions by 7 metric tons and carbon dioxide emissions by 659 metric tons annually.[62]

• *Crane Valves.* In the face of strong foreign competition undercutting the foundry business, Crane Valves of Washington, Iowa needed to cut manufacturing costs to save jobs. Assisted by the Metal Casting Center at the University of Northern Iowa, Crane-Washington implemented a "total assessment audit" of its plant. The audit brought in six public- and private-sector organizations with expertise in energy efficiency, productivity improvement, and waste reduction. The audit catalyzed a total quality management program that delineated a host of capital and non-capital improvement initiatives—all of which focused on energy-use efficiencies, productivity improvements, and process management. The audit assessed energy use in all process cycles, including the materials, equipment, and tooling cycles of foundry operations.

With funding from the ***Iowa Energy Center*** in Ames, Crane-Washington launched a demonstration project at its facility that could serve as a model for the entire foundry industry. The results are striking: kilowatt-hours per ton of materials were slashed by 29 percent; scrap was cut by 39 percent; error rates dropped by 28 percent; and the number of labor-hours per ton of poured materials fell 27 percent. All this while productivity soared: the average tons per day of materials poured increased an astounding 78 percent, while the number of good molds poured daily increased 42 percent. To top it off, new jobs increased by 30 percent from November 1993 through October 1994.[63]

• *Dow Chemical.* Often the best efficiency investments begin with employee suggestions, which, when implemented systematically, can bolster productivity and expand the company, creating jobs. Dow Chemical's Louisiana Division, whose 2,400 employees in more than 20 plants produce chemicals like propylene, began a yearly contest in 1982 to find energy-saving projects that paid for themselves in one year (a return on investment of more than 100 percent) and that required a capital investment of less than $200,000.[64]

The first year, the program had 27 winning projects that required a total capital investment of $1.7 million with an average return on investment of 173 percent. Dow's energy manager, Kenneth Nelson, reported that after the first 27 projects "many people felt there couldn't be others with such high returns." The skeptics were wrong. The 1983 contest had 32 winners. The projects they suggested required a total capital investment of $2.2 million and provided a 340 percent return on investment—producing savings for the company of $7.5 million in the first year and every year after that.[65]

The yearly contest was so successful that Dow eliminated the $200,000 limit and included savings from all kinds of waste reduction, not just energy. Winning suggestions included more efficient pumps and installation of heat exchangers to salvage waste heat. Others involved sophisticated process redesign. An ethic of "continuous process improvement" began to pervade the company. Employees received engraved plaques in a formal awards ceremony, and in addition, were often rewarded by their supervisors through job performance raises.

For 575 projects throughout the 1980s, the average return was 204 percent (audited). After ten years and nearly 700 projects, the 1992 contest had 109 winning projects with an average return of 305 percent, and the 1993 contest had 140 projects with an average return of 298 percent.[66]

D. Conclusion

The best industrial efficiency programs start with employee suggestions, which subsequently must be supported by determined management and by federal, local, or utility financing and technical support. Communicating to plant staff members that energy efficiency is a priority and encouraging them to identify energy-saving opportunities taps the know-how of those closest to the manufacturing process—which can have extraordinary results.

A key lesson from these industrial case studies is that process manufacturing efficiency improvements require a pervasive ethic of constant feedback from all members of a business. Efficiency improvements are rarely one-shot investments. Continuous improvement in energy efficiency and waste reduction can boost productivity and competitiveness—while empowering employees. It takes people—not just technology—to save energy, expand a business, and improve the environment at the same time.

II. The Utility Industry: Efficiency Successes

America's utilities provide roughly $260 billion each year in energy services to homes, businesses and industries—5.2 percent of the gross national product.[67] Electric and gas utilities have capital assets worth $790 billion.[68] Energy production and consumption by utilities involves enormous environmental costs: the nation's electric utilities released approximately 500 million metric tons of carbon in 1993, which is about 36 percent of the annual U.S. total.[69]

A. Utility Efficiency Has Improved Markedly

During the past two decades, the utility sector has made significant progress in improving electric energy efficiency. Between 1960 and 1973, U.S. electricity use grew at an average rate of 7.3 percent per year, almost double the 4 percent growth per year in GDP.[70] Between 1973 and 1986, however, growth in electricity use fell to 2.4 percent per year. Some 26.6 quads of anticipated energy usage per year never materialized, mostly due to improved energy efficiency.[71] Greater efficiency was caused by a combination of factors, including structural changes in the U.S. economy (including the shift from manufacturing to services), changes in electricity and fossil-fuel prices, development and commercialization of new energy-efficient products and services, government energy-efficiency programs, and utility demand-side management (DSM) programs.[72]

B. Integrated Resource Planning Has Been a Demonstrated Success

During the past five years, federal, state, and public utility commission regulators have adopted regulations that successfully promote energy efficiency and renewables development. Among these successes has been adoption of a regulatory model known as "integrated resource planning" (IRP), or least-cost energy planning. Initially mandated in California in 1990, IRP involves ranking all energy sources, including improvements in energy efficiency, by cost. An energy-efficiency improvement must be implemented first—before the acquisition of new generating capacity—if the improvement costs less per kilowatt-hour *avoided* than new supply would cost.

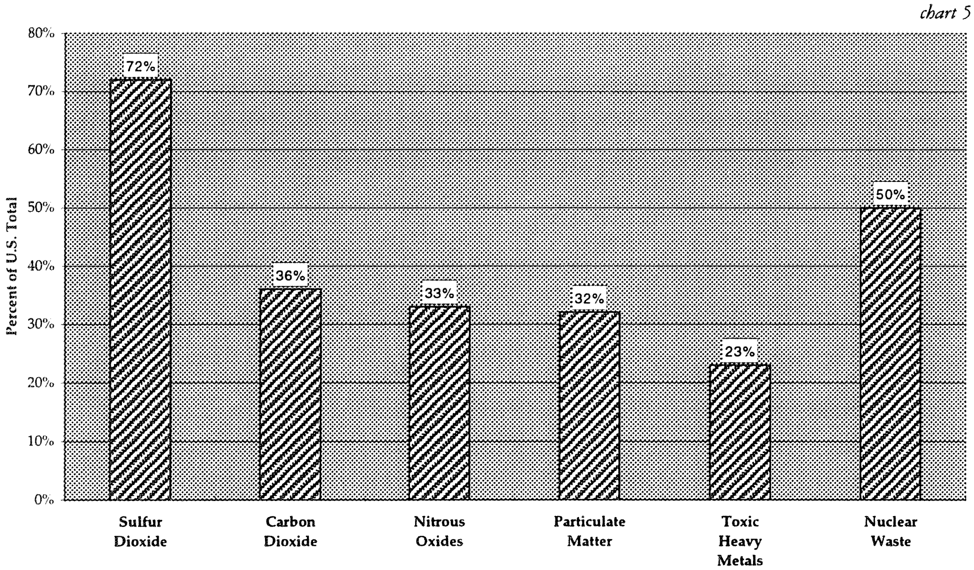
Although most states now claim to have adopted IRP procedures to some degree, only 10 have a regulatory framework that genuinely ensures that DSM can compete on an equal footing with supply options.[73]

C. Regional Demand-Side Management Programs Have Been Successful Nationwide

In response to IRP policies, billions of utility dollars have been diverted away from building new generation capacity. The money instead has gone into DSM programs to reduce demand. From 1990 to 1994, utility investments in DSM programs and energy efficiency tripled to $3 billion per year. These investments reduced national generation 2 percent per year, while consumers saved nearly $4 billion annually on their utility bills. A 1993 EPRI survey of most U.S. DSM programs[74] found that the programs save electricity at an average cost of just 2.1 cents per kilowatt-hour.[75] Utility spending on DSM programs increased dramatically between 1989 and 1993, growing from 0.5 to 1.5 percent of utility operating revenues. In 1993, U.S. electric utilities spent $2.8 billion on DSM programs.[76] These expenditures paid substantial benefits, including electricity reductions in 1993 of 44,000 gigawatt-hours and peak demand reductions of 40,000

U.S. Utilities' Contribution to Total Air Emissions

chart 5



Source: Environmental Protection Agency, Energy Foundation megawatts. These reductions are equivalent to 1.6 percent of annual electricity sales and 6.8 percent of summer peak demand, and reduced U.S. carbon dioxide emissions by approximately 27.8 million metric tons.[77] In 1994, utility DSM programs cut potential summer peak demand by 7 percent and annual electricity use by 2 percent nationwide.

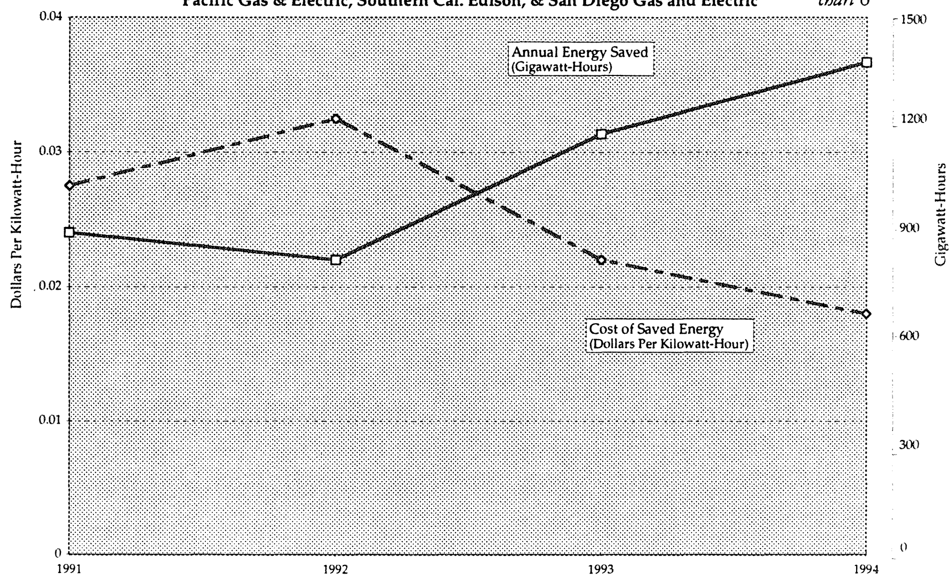
Despite current uncertainties in utility markets due to industry restructuring, DSM programs are expected to expand, and could reduce national electricity demand by 3 percent annually by the year 2000. This continued expansion could reduce electricity generation by 71,000 gigawatt-hours in the year 2000, preventing 44.9 million metric tons of carbon dioxide emissions annually.[78]

Over the last decade of incorporating IRP into utility planning, literally hundreds of utility DSM programs have emerged. Utilities used DSM to retain customers, to increase market share, and to enhance profitability by improving customer services. DSM programs will become even more important in a restructured utility industry, as still-regulated distribution companies will select the low-cost option for providing energy needs. The following success stories, categorized by region, demonstrate the financial savings—and substantial environmental and health benefits—of utility efficiency programs.

1. California DSM Successes

DSM programs in California provided net life-cycle benefits of $2.2 billion during the period 1990 to 1994.[79] In 1994, the average cost of saved kilowatt-hours was less than two cents per kilowatt-hour.[80] By 1994,

Costs and Savings of California DSM Programs
Pacific Gas & Electric, Southern Cal. Edison, & San Diego Gas and Electric *chart 6*



Source: Natural Resources Defense Council

California DSM programs were saving 1 percent of system consumption each year—and companies and residences were not even touching the limits of their efficiency capacity.[81]

• ***Pacific Gas and Electric.*** Pacific Gas and Electric (PG&E), California's largest utility, was one of the first in the country to implement utility efficiency programs. PG&E's Direct Assistance programs, over their ten-year history, have weatherized more than 600,000 low-income homes with attic insulation, weather stripping, shower heads, caulking, water heater blankets, and duct wraps, at a total program cost of $245 million.[82] In addition, since 1987, the program has replaced more than 90,000 appliances—primarily refrigerators that exceed federal appliance efficiency standards, but also furnaces, evaporative coolers, and water heaters—with energy-efficient models at no charge to low-income customers. It also installed more than 70,000 compact fluorescent lamps. In 1992, the programs saved 16,283 megawatt-hours of electricity, which prevented 5,585 metric tons of carbon dioxide emissions. Over their life-cycle, however, the efficiency installations from 1987 through 1992 saved 1,901 gigawatt-hours, resulting in a cumulative reduction in carbon dioxide emissions of 652,000 metric tons.[83]

PG&E's Model Energy Communities Pilot Project targeted the Antioch/Brentwood area northeast of Oakland, California, which was slated for construction of a new substation to handle a spike in demand when homeowners concurrently switched on air conditioners at the end of summer workdays. PG&E installed innovative demand-side management technologies that targeted this specific community, including compact fluorescent bulbs, low-flow shower heads, shell improvements, duct repair, insulation, sun screens, and air-conditioner tune-ups. PG&E also downsized air-conditioner units to better fit room conditions.[84] At a cost of $8.9 million, PG&E saved

4,322 megawatt-hours of electricity between 1991 and 1993, which prevented 1,482 metric tons of carbon dioxide emissions. Over the life-cycle of the energy saving installations, 86.4 gigawatt-hours are expected to be saved, corresponding to a cumulative carbon dioxide reduction of nearly 30,000 metric tons.[85]

• ***Southern California Edison.*** Southern California Edison (SCE) created one of the more innovative lighting DSM programs when it awarded compact fluorescent lamp manufacturers wholesale rebates of $5 per unit, creating a "downstream" price reduction at the retail level. Because retailers traditionally double or treble their wholesale costs, customer rebates reached as high as $15 with each $5-per-bulb manufacturer's rebate. The wholesale rebates spurred manufacturer participation, while bulk rebates allowed SCE to stipulate performance specifications during manufacturing, including minimum efficiency requirements for each bulb. SCE achieved high participation by both residential and commercial consumers, while transforming the market away from old, inefficient incandescent lighting.[86] Residences saved 101,057 megawatt-hours of electricity annually because of the program, a reduction in demand that cut carbon dioxide emissions by 34,650 metric tons each year. Carbon dioxide reductions over the life-cycle of the new bulbs will total 225,300 metric tons. Commercial customers saved 118,979 megawatt-hours per year, with annual carbon dioxide reductions of 40,800 metric tons and life-cycle reductions of 265,250 metric tons.[87] The combined cost of the residential and commercial programs from 1992 through 1994 was $14,425,429.

• ***Sacramento Municipal Utility District.*** The Sacramento Municipal Utility District (SMUD) is a case study of an impressive utility turnaround. On the heels of a voter referendum to shut down its Rancho Seco nuclear power plant in the late 1980s, SMUD closed the plant and ushered in a new era at the utility. SMUD set out to secure 800 megawatts from DSM programs and 400 megawatts from renewable energy sources. Under the leadership of David Freeman, SMUD boosted its DSM budget from $3.8 million to $38 million in 1991.

By 1993, SMUD's Energy-Efficient Refrigerators program, for example, had resulted in purchases of more than 70,000 energy-efficient refrigerators while 63,000 old, inefficient refrigerators were collected and recycled. SMUD's Direct Investment Program has provided electric-heat customers with almost 15,000 energy-efficiency measures for free. Participants in the Residential Peak Corps Program, SMUD's leading load-management program, have installed 96,130 air-conditioning cyclers. Participants in the Shade Tree Program have planted 109,000 trees, and 1,200 solar water heaters have been installed through the Solar Domestic Water Heater Program, which SMUD has expanded to promote rooftop solar photovoltaics. Equally impressive results have accrued from SMUD's commercial and industrial retrofit programs.[88]

These programs saved, in 1993, 96.4 gigawatt-hours of electricity—which avoided 33,000 metric tons of carbon dioxide emissions in that year. During the life-cycle of SMUD's DSM and renewable-energy programs, including all efficiency installations made between 1978 and 1993, 4,039 gigawatt-hours will be saved, including 309 megawatts of capacity savings, at a total cost of $196 million. That represents a reduction of 1.38 million metric tons of carbon dioxide emissions.[89]

SMUD helped one of its industrial customers, ***Blue Diamond Almonds,*** become significantly more energy efficient. Blue Diamond installed energy-efficient lighting in its warehouses and offices, saving $52,000 annually. Heating equipment upgrades added another $18,000 in annual energy savings. A similar SMUD-supported energy-efficiency program for ***Intel,*** the large semi-conductor manufacturer, convinced the company to expand its operations in Sacramento, adding 250 jobs.[90]

• ***California Energy Commission.*** The California Energy Commission (CEC) seeks to cut the energy demand of local government facilities through its "Energy Partnership Program," which provides technical and financial assistance for energy upgrades at city and county facilities throughout California. The program has supplied technical assistance to existing public facilities, providing efficiency upgrades (compact fluorescent lamps, ballasts, occupancy sensors, thermostat controls, energy management systems, variable frequency drives, HVAC improvements) to city halls, administration buildings, libraries, fire and police departments, jails, hospitals, and wastewater treatment plants. CEC facilitates project financing through its own revolving loan fund, federal funds, utility assistance, energy service companies, or other outside funding sources.[91] The Energy Partnership Program has been a dramatic success, saving 15.7 gigawatt-hours of electricity in 1992 at a cost of $6.5 million, while preventing 5,385 metric tons of carbon dioxide emissions. Cumulative savings include 165.9 gigawatt-hours from upgrades installed from 1989 through 1993, avoiding 56,900 metric tons of carbon dioxide emissions at a total cost of $17.3 million.[92]

2. Pacific Northwest DSM Successes

In 1995, the Pacific Northwest (Washington, Oregon, Idaho, and Montana) was enjoying nearly 900 average megawatts of electricity savings as a result of DSM efforts—annual savings equivalent to the power output of four good-sized gas-fired combustion turbines. Conserved energy totaled over 50,000 gigawatt-hours in 1995 at an average cost of 2 to 2-1/2 cents per kilowatt-hour—well below the next most costly resource alternative available. These DSM programs were saving retail consumers $2 billion per year while avoiding carbon dioxide emissions of approximately 5.35 million metric tons annually.[93]

- *Portland Energy Office.* In 1993, Portland, Oregon became the first U.S. city to adopt a local carbon dioxide reduction strategy, committing to reduce its carbon dioxide emissions by 20 percent below 1988 baselines by the year 2010. This target is a greater reduction than the United States committed to under the 1992 Framework Convention on Climate Change.[94]

Portland's "Multifamily Energy Savings" program, initiated in 1987, exemplifies the city's long-standing commitment to energy efficiency. It is intended to target the split incentive between landlord and tenants—where tenants typically pay utility bills, leaving landlords little incentive to make efficiency improvements. The program encourages retrofits by marketing existing efficiency services—such as utility audits, rebates and loans, plus state tax credits—to building owners. By promoting a diverse package of financial incentives, the program has made building owners in Portland surprisingly receptive to investing in energy-efficiency measures like windows, insulation, common area lighting, water heaters, air sealing, and heating system improvements. To date, the program has weatherized more than 11,050 apartment units, producing savings of approximately 1,200 kilowatt-hours annually per unit. The highly successful program saved 1,412 megawatt-hours (avoiding 151 metric tons of carbon dioxide) in 1993 alone, and should save 375,570 megawatt-hours over the projected life-cycle of the improvements (avoiding 40,186 metric tons of carbon dioxide). It achieved these savings at a cost of less than 1 cent per kilowatt-hour saved.[95]

- *Bonneville Power Administration.* The city of Ashland, Oregon developed one of America's premier resource conservation initiatives in a small community. The city's Conservation Division worked with the Bonneville Power Administration—the region's wholesale power supplier—to implement a range of energy-efficiency measures, for both new construction and retrofits, that conserve electricity, gas and water, and reduce waste. The measures include weatherization, "Good Cents" new homes, showerheads, and composting. More than half the savings have been generated in the residential sector, lowering customers' bills and improving occupants' comfort. Ashland has also addressed the land-use implications of development, and has implemented a comprehensive set of land-use ordinances to minimize negative aspects of development. For example, the city rewards resource efficiency in new developments by issuing "conservation bonuses" that allow developers to build more units than normal, increasing density while easing travel, sprawl, and demands on gasoline and air quality. Ashland's comprehensive resource-efficiency approach has created nearly 10,000 megawatt-hours in annual savings while cutting carbon dioxide emissions by 1,070 metric tons annually. Cumulative savings from 1980 through 1994 come to 66,000 megawatt-hours of electricity and 7,062 metric tons of carbon dioxide emissions. Over the life-cycle of the efficiency installations, more 26,000 metric tons of carbon dioxide will be saved.[96]

Bonneville's "WaterWise" program is an agricultural initiative that involves a comprehensive effort to conserve irrigation water and energy while improving crop yields, thanks to the precision application of water. WaterWise provides technical, financial and informational services to farmers east of the Cascade Mountains in Washington and Oregon. The program focuses on irrigation system testing and design work, hardware retrofits (including low pressure, mainline, and pump modification equipment), and irrigation management, and it provides farmers with detailed information on weather patterns and evapotranspiration rates for optimal crop watering. For an investment of $24.5 million, Bonneville has saved 506.3 gigawatt-hours of electricity over the decade 1983 through 1993—which corresponds to a carbon dioxide emissions savings of more than 61,250 metric tons. Over the life-cycle of the improvements installed during that decade, 1,419 gigawatt-hours will be saved, reducing carbon dioxide emissions by 171,700 metric tons.[97]

Bonneville Power administered an Aluminum Smelter Conservation/ Modernization program in the late 1980s that was responsible for enormous energy savings. The ten primary smelters in Bonneville's service territory consume one-third of all Bonneville power—15 percent of all electricity used in the Northwest (sold by Bonneville and other utilities). Aluminum production is a highly electricity-intensive industry, with electricity purchases comprising roughly 25 percent of operating costs. The objective of the Conservation/ Modernization program was to encourage smelters to improve the efficiency of their industrial processes, both to remain competitive and to free up electric supply for other Northwest uses. Bonneville paid the smelters incentive payments for baseline efficiency improvements equal to half a cent per kilowatt-hour saved over a 10-year period, which is about one-third of the cost of efficiency improvements. The program has achieved electricity savings of 4.1 percent of total industrial sales—equal to 1,057.8 gigawatt-hours saved per year, and 225,311 metric tons of carbon dioxide emissions reduced annually.[98]

- ***Puget Sound Power & Light.*** Puget Power's "Commercial and Industrial Electricity Conservation Service," begun in late 1978, was one of the first DSM programs to be offered to the commercial sector. Puget's philosophy has been to provide valuable customer services while controlling load growth. Puget's staff includes a highly-trained cadre of engineers with the technical expertise necessary to analyze commercial and industrial facilities. Their analyses have taken a whole-facility, customized approach; they look at all facets of electricity use and assess efficiency upgrades, including process systems, the building envelope, space conditioning, lighting applications, and water heating improvements. Puget uses a total resource cost basis for measuring cost effectiveness, and pays for upgrades based on the utility's avoided cost, a value that reflects the full life-cycle of each improvement. Typical incentive payments equal 60 to 80 percent of customers' total installation costs—a level that significantly exceeds most utility rebate programs. Puget generally ends up paying out about half its avoided cost. For instance, in 1992 the program cost an average of 3.3 cents per kilowatt-hour, while its avoided cost for measures with an average life-cycle of 15 years was 6.5 cents per kilowatt-hour. Efficiency improvements installed during 1992 saved 122 gigawatt-hours in that year (16,958 metric tons of carbon dioxide saved) at a cost of $25.5 million, with life-cycle energy savings from those improvements totaling 1,823 gigawatt-hours, which should cut carbon dioxide emissions by 253,397 metric tons. Since the program began, the life-cycle savings of improvements installed between 1978 and 1992 are 6,356 gigawatt-hours at a total cost of $101.25 million, avoiding 883,484 metric tons of carbon dioxide emissions.[99]

- ***Seattle City Light.*** Seattle City Light, one of the nation's largest municipal utilities, reinforces the notion that utilities can effectively offer DSM services in regions characterized by low power rates. In 1993, Seattle City Light budgeted a precedent-setting 9.1 percent of gross revenues for DSM. The utility's early emphasis on energy efficiency, however, came only after a lawsuit overturned the utility's planned investment in the Washington Public Power Supply System (WPPSS), a proposed series of nuclear plants. The WPPSS decision changed the utility's course, prodding it to become one of the nation's leaders in energy efficiency.

Seattle City Light's comprehensive DSM programs cover the residential, commercial and industrial sectors, and have included weatherization, lighting, energy-efficient water heaters, and water efficiency measures, as well as industrial and commercial efficiency improvements for motors and HVAC systems. This success has been supported by the Bonneville Power Administration, which over time has funded nearly one-quarter of Seattle City Light's DSM expenditures. In 1993, efficiency improvements installed that year cut energy demand by 52,629 megawatt-hours (producing a carbon dioxide reduction of 7,315 metric tons), which will save 885,294 megawatt-hours over the life-cycle of those improvements (reducing carbon dioxide emissions by 123,055 metric tons). Cumulatively, since the DSM programs began in 1978, Seattle City Light efficiency programs have saved 2,454,256 megawatt-hours (341,141 metric tons of carbon dioxide). Over the life-cycle of the installations, 7,380,743 megawatt-hours will be saved—for a total life-cycle carbon dioxide reduction of 1,025,923 metric tons.[100]

3. NEW ENGLAND DSM SUCCESSES

In 1990, New England Electric System earned $8.3 million, a 12 percent return, on DSM programs. By 1991, New England utilities' DSM expenditures had increased to about $300 million annually, with the majority of those expenditures targeted for energy efficiency rather than load management. These investments have resulted in significant economic, environmental, and energy-security benefits. For example, in 1991, utility DSM investments in New England:

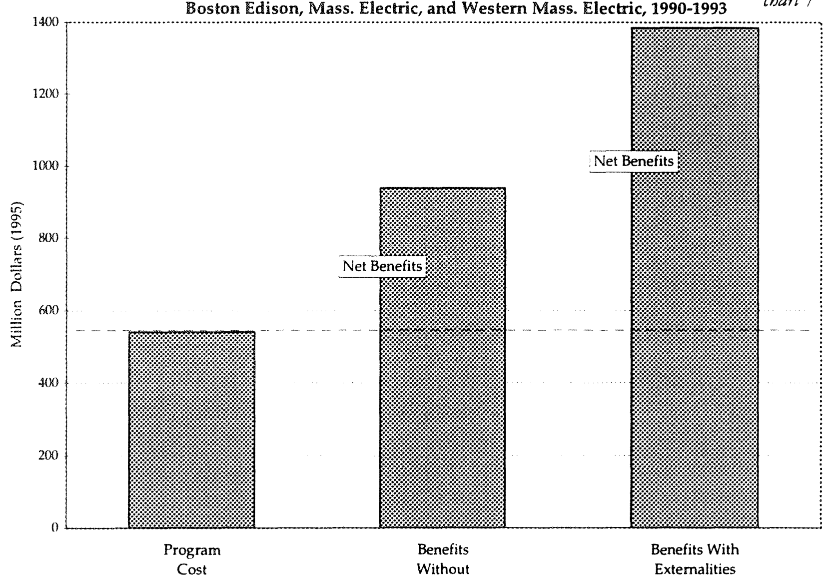
- were saving 2,169 gigawatt-hours of energy annually, enough to heat and power the New Haven metropolitan area;
- produced energy-efficiency improvements that will lower net electric bills by approximately $250 million over their life cycle;
- saved the equivalent of 3.7 million barrels of oil;
- avoided emissions of 11,800 metric tons of sulfur dioxide;
- avoided emissions of 5,000 metric tons of nitrogen oxides; and,
- avoided emissions of 1.8 million metric tons of carbon dioxide.[101]

Three of the largest utilities in Massachusetts have worked collaboratively with environmental and consumer groups to design and implement DSM programs. From 1990 through 1993, investments in DSM by these utilities grew, such that by 1993, DSM outlays reached 5 percent of annual utility retail revenues. During that four-year period, investments totaled $540 million, including both utility and participant costs, for measures that produced energy savings at an average life-cycle cost of 3.8 cents per kilowatt-hour. The life-cycle savings total 14,091 gigawatt-hours and provide 267 megawatts of summer peak reductions. Carbon dioxide reductions over the life cycle of the measures total 9.3 million metric tons.[102] In 1994, the DSM programs of these three utilities accounted for about 3 percent of customer energy requirements. The net value of customer savings exceeded $843 million, including environmental benefits ($398 million if environmental externalities are excluded). The energy-efficiency investments have helped to defer investments in additional capacity.[103]

- *New England Electric System.* In 1987, New England Electric System, which comprises three utilities—***Massachusetts Electric, Narragansett Electric,*** and ***Granite State Electric***—initiated its "Design 2000" program, which focuses on implementing efficiency upgrades at the time customers install new electrical equipment during the normal course of business. These "time dependent" opportunities occur during new construction, renovation, and when failed equipment is replaced. Design 2000 pays essentially all out-of-pocket expenses associated with the efficiency upgrades, which include lighting, motors and drives, HVAC upgrades, food-service and industrial-process improvements, and custom measures that employ emerging technologies—and then provides the participant with lower electricity bills. Energy savings from 1993 efficiency upgrades alone were 28,972 megawatt-hours (saving 15,935 metric tons of carbon dioxide emissions), while the life-cycle savings of the measures installed in that year will be 416,276 megawatt-hours (a

Benefits of New England DSM Programs:
Boston Edison, Mass. Electric, and Western Mass. Electric, 1990-1993

chart 7



Source: Susan Coakley and Jeff Schlagel

carbon dioxide emissions reduction of 228,952 metric tons). Cumulatively since 1989, 66,220 megawatt-hours have been saved (preventing 36,421 metric tons of carbon dioxide emissions), while the life-cycle energy savings of upgrades to date will be 923,374 megawatt-hours (avoiding carbon dioxide emissions of 530,017 metric tons). The Design 2000 program has saved New England Electric 14.16 megawatts of new capacity at a total, cumulative program cost of $21.3 million.[104]

• ***Burlington Electric Department.*** Burlington has served the residents of Burlington, Vermont with a mix of electricity and energy-efficiency services since the late 1970s. At that time, it responded to the oil shocks by introducing its first energy-efficiency programs. More recently, local concerns over power purchases from Hydro-Quebec and its controversial James Bay development prompted Burlington voters to pass an $11 million bond issue to catalyze DSM programs. The utility introduced a "Smartlight" leasing program for compact fluorescent lamps, and promoted a program to convert electric resistance heating to other fuels in order to reduce winter peak load. Six other programs offer customers a comprehensive package of DSM options. Cumulative energy savings from 1991 through 1993 totaled 33,944 megawatt-hours (preventing 2,444 metric tons of carbon dioxide emissions), and over the life cycle of these installations will save 290,183 megawatt-hours (preventing 20,893 metric tons of carbon dioxide emissions).[105]

4. New York DSM Successes

DSM programs in New York provided net life-cycle energy savings to customers of $1.4 billion during the period 1990 to 1994.[106]

• ***Consolidated Edison.*** Consolidated Edison's "Commercial & Industrial Efficient Lighting Incentives Program" provides commercial and industrial customers with lighting rebates of 25 cents per watt of lighting load removed for fluorescent ballast upgrades. Lighting control devices are rebated at 10 cents per watt of connected lighting load. Under the Shared Energy Savings financing approach, Con Edison provides up-front installation costs with customer repayment derived from energy savings over a payback period of up to five years. Under this approach, Con Edison recovers its costs while customers receive the benefits of an immediate positive cash flow from energy savings without any capital outlay requirements. From 1990 through 1994, the program achieved approximately 1,251 gigawatt-hours of annualized energy savings and 311 megawatts of system peak reductions, cutting carbon dioxide emissions by 587,970 metric tons.[107]

Con Edison's "Commercial & Industrial High Efficiency Motor Incentive Program" encourages commercial and industrial customers to install high-efficiency electric motors and variable frequency drives (VFDs). Con Edison pays $10 per horsepower for motors meeting the utility's minimum efficiency standards, which fully offsets the differential equipment cost incurred by customers. The current incentive level for VFDs is either $50 or $90 per horsepower depending upon the pump and fan HVAC application. Here again, a Shared Energy Savings approach is offered as an alternative to rebates. From 1990 through 1994, this successful program saved approximately 137 gigawatt-hours in annualized energy and reduced the system peak by approximately 5 megawatts, and cut carbon dioxide emissions by 64,390 metric tons.

Con Edison's "Dealer Incentive Programs" are point-of-purchase incentive programs for retail businesses that sell energy-efficient appliances and equipment. Con Edison encourages retail salespeople and their managers to sell high-efficiency units, such as air conditioners and refrigerators, by awarding credits which are redeemable for merchandise or travel. No direct incentives are offered to customers. The program is transforming the appliance and equipment market: appliance dealers have substantially increased their stock of highly-efficient appliances. From 1990 through 1994, this and other of Con Edison's residential DSM programs have saved approximately 60 gigawatt-hours in annualized energy and reduced the system peak by approximately 28 megawatts, cutting carbon dioxide emissions by 28,200 metric tons.

Other Con Edison DSM programs include the "Commercial & Industrial High-Efficiency Electric Space Conditioning Incentive Program," "Steam Air-Conditioning Program," "Commercial & Industrial Customized Energy-Efficiency Program," "Curtailable Electric Service Program," "Residential Compact Fluorescent Program," and "Residential Submetering Program." Con Edison's DSM programs have saved over 1,800 gigawatt-hours on an annualized basis during the 1990-1994 period, with associated peak demand savings of about 585 megawatts. The programs have avoided 846,000 metric tons of carbon dioxide emissions.[108]

5. Wisconsin DSM Successes

Wisconsin utilities achieved a cumulative reduction in energy demand from 1988 to 1994 of 2,959 gigawatt-hours, which avoided 1.8 million metric tons of carbon dioxide emissions. In 1994 alone, Wisconsin's DSM programs saved 549 gigawatts, which cut carbon dioxide emissions in that year by 334,000 metric tons. Such savings are projected to continue, albeit at a declining rate, primarily due to uncertainties surrounding utility industry restructuring. Savings in 1995 are projected to be 451 gigawatt-hours, cutting carbon dioxide emissions by 274,000 metric tons. Cumulatively from 1995 through 2013, projections show that Wisconsin DSM programs could reduce electricity usage by 5,152 gigawatt-hours, which could prevent more than 3.1 million metric tons of carbon dioxide emissions. [109]

- *Wisconsin Electric.* Wisconsin Electric assists in providing energy-efficient, affordable housing for low- and moderate-income families. Through several innovative grant and loan programs, Wisconsin Electric seeks to instill an energy-efficiency ethic among low-income housing providers, community-based service agencies, and low-income energy customers. Projects have included installing energy-efficient fluorescent lights and refrigerators in a newly renovated emergency shelter in Milwaukee, in 13 low-income apartments in a recently converted building that had been a vacant elementary school, and in 18 transitional housing units in a joint project with the Milwaukee YWCA. The lighting retrofit saves the YWCA more than 15,000 kilowatts annually, and prevents more than 9 metric tons of carbon dioxide emissions each year. Wisconsin Electric also installed electric energy-efficiency measures in ***Goodwill Industries*** facilities that annually save an estimated $33,000 in electric bills. Another project teamed Wisconsin Electric with the Milwaukee Housing Authority to upgrade the electrical efficiency of 527 public housing units. Wisconsin Electric programs target low-income customers who do not have the financial resources to invest in energy conservation measures. Through these programs, Wisconsin Electric has cut energy demand by more than 4.4 million kilowatt hours—preventing some 2,680 metric tons of carbon dioxide emissions.[110]

- *Madison Gas and Electric.* A small, investor-owned utility that sells both electricity and gas, Madison Gas and Electric (MGE) has been a pioneer in DSM programs. A 1991 DOE study found MGE to be one of nine leading utilities nationally in the delivery of rebate programs. Through its "Residential Lighting Program," MGE has been able to shift the Madison market away from incandescent lighting and into a reliable market for high-efficiency products, achieving maximum customer and utility energy savings at the least cost. For instance, in 1990 there were only four retailers in MGE service territory selling six models of compact fluorescent lamps. Now there are 62 retailers (out of 100 total retailers) selling a total of 63 models of compact fluorescents. MGE distributes rebate coupons for $5 or $10 off eligible lighting measures, and $15 or $30 off other measures, to both end-use customers and to retail stores. MGE offers to pay 50 percent of retailer costs for cooperative energy-efficient lighting advertising. MGE provides lists of retailers stocking compact fluorescents to its customers, and assists with in-store displays. Sales have skyrocketed so much that MGE has been able to slowly phase-out rebates and move toward consumer education to continue high sales volumes. Cumulative energy savings since 1990 are 23,799 megawatt-hours, saving 738 kilowatts of capacity, and avoiding 14,494 metric tons of carbon dioxide emissions at a program cost of $1.5 million.[111]

D. Federal Initiatives Continue to Spur Efficiency Successes

Federal and state support for efficiency programs has been critical to the success of programs nationwide. According to the Congressional Research Service, the federal government has spent a total of $5.7 billion on energy-efficiency research and development since 1973. Technologies advanced by these efforts have saved American homeowners and businesses $226 billion, and will save billions more over the life cycle of the efficiency improvements.[112] Several of the federal program success stories are reviewed below.

• ***U.S. Environmental Protection Agency and U.S. Department of Energy "Climate Wise" Program.*** Administered jointly by the EPA and DOE, the Climate Wise program is a voluntary program that works with businesses (with a focus on manufacturing firms) to install cost-effective energy efficiency and pollution prevention strategies. Climate Wise participants currently represent almost 4 percent of U.S. industrial energy use.

By joining Climate Wise, businesses agree to initiate, expand, or accelerate a set of cost-effective measures to improve efficiency, including (1) improving equipment and manufacturing process efficiencies, (2) utilizing fuel switching and improved management practices, (3) integrating efficiency into new product design and manufacturing, and (4) participation in other federal voluntary programs, such as Green Lights (to install efficient lighting), Motor Challenge (to improve motor efficiencies), Waste Wi$e (to integrate waste reduction strategies), and NICE[3] (to demonstrate energy-efficient, pollution-preventing technologies). Companies that have initiated Climate Wise programs have achieved significant economic and environmental benefits. By the year 2000, current Climate Wise companies expect to save more than $80 million annually.

In return for their participation, Climate Wise companies receive technical assistance from federal agencies and national laboratories, utilities, trade associations, and state and local energy, pollution prevention, and economic development offices. Business-to-business exchange workshops facilitate replication of successful efficiency models. Financial assistance can be arranged through guaranteed loans, low-interest buy-downs from state providers, state tax credits, utility programs, and private-sector financing opportunities. Climate Wise "showcases" projects and businesses that demonstrate significant greenhouse gas emissions reductions, and sponsors media events, awards programs, and other promotional activities.[113]

Dupont, headquartered in Wilmington, Delaware, has installed energy-efficiency improvements through the Climate Wise Program that are currently saving $31 million annually. Dupont estimates that further energy-efficiency improvements, including fuel switching, improved steam balance and waste heat reductions, will reduce carbon dioxide emissions by 18 million metric tons annually by the year 2000 from 1990 emission levels.[114]

AT&T, in Basking Ridge, New Jersey, is installing efficiency improvements through the Climate Wise program projected to save the company $50 million each year and offset 154,000 metric tons of carbon dioxide annually by the year 2000.[115]

• ***U.S. Department of Energy "Climate Challenge" Program.*** The United States was one of 154 nations and the European Community to sign the United Nations Framework Convention on Climate Change (FCCC) in Rio de Janeiro in 1992.[116] Domestic implementation of the U.S. commitment—which is to reduce U.S. greenhouse-gas emissions to 1990 levels by the year 2000—follows mostly voluntary measures set forth in President Clinton's Climate Change Action Plan. The plan, issued in October 1993, seeks 108 million metric tons of carbon dioxide reductions and calls on electric utilities to provide much of those reductions.[117]

Climate Challenge is the primary element of the plan that directly involves electric utilities. As of March 1995, 79 utilities, representing more than half of U.S. electricity generation, had signed agreements with DOE to participate in Climate Challenge, pledging to reduce carbon dioxide emissions by 41 million metric tons by the year 2000. DSM programs account for 18 percent of the reductions planned in Climate Challenge.[118]

- ***Federal Energy Management Program (FEMP).*** As the world's largest consumer of goods and services, the federal government has a major impact on the marketplace. Energy consumption by the federal government can be reduced substantially through energy-efficiency measures. FEMP coordinates the reduction effort. If all agencies implemented the FEMP requirements of the Energy Policy Act of 1992 (EPAct) and Executive Order 12902,[119] the agencies would save as much as $400 million annually by 2000 and $1 billion annually by 2005.[120] FEMP has successfully cut net energy consumption by 20 percent in four federal agencies (Energy, Interior, Justice, and the Federal Emergency Management Agency), and by 10 percent in six more (Agriculture, Defense, Transportation, Veterans Affairs, General Services Administration, and NASA). One of FEMP's strengths is its ability to attract outside resources to aid in the task of saving energy; the program leverages about $3 in savings for every dollar of taxpayer expenditures.[121] FEMP's efforts have cut the equivalent of 3 million metric tons of carbon dioxide emissions.[122]

- ***U.S. Department of Energy "Weatherization Assistance Program."*** The DOE's Weatherization Assistance Program (WAP) provides, through state energy offices, grants to community-based service providers for weatherization of low-income family residences, particularly those housing children, the elderly, and disabled family members. Since its inception in 1976, WAP has lowered the energy costs of more than 4.4 million homes, saving the equivalent of 12 million barrels of oil. A typical family served by the program has an annual income of $7,641, and as a result of the program, saved 18.2 percent off their annual heating costs. State and local agencies have leveraged more than $200 million each year to increase the number of assisted homes to about 225,000 annually. In fiscal year 1996, WAP is slated to weatherize an additional 116,145 homes. A 1990 Oak Ridge National Laboratory study determined that for every dollar invested by DOE in WAP, $1.72 in energy savings results. WAP is also responsible for substantial job creation—52 jobs for every $1 million of federal funds invested, plus another 22 indirect jobs.[123]

- ***State Energy Conservation Program.*** The federally-supported State Energy Conservation Program (SECP) provides the resources for many of the services provided by state energy offices. SECP funds are used nationwide for energy training, waste minimization, recycling, home energy rating systems, computerized bus routings to save energy, energy emergency planning, promotion of natural gas vehicles, and many other activities. Many states use SECP funds to provide technical assistance to businesses and industries for reducing their energy consumption, thus reducing associated costs.[124]

- ***Institutional Conservation Program.*** The Institutional Conservation Program (ICP) provides matching funds and technical assistance to schools and hospitals for energy-saving capital improvements for buildings, equipment, mechanical systems, and controls. Approximately 65,000 buildings—22 percent of all eligible structures in the country—have had energy improvements through ICP. DOE estimates the cumulative energy cost savings directly attributable to ICP-supported retrofits totaled $4.1 billion through 1991. The ICP typically provides 50 percent of the efficiency investment costs, which are matched either by state or private sources. The average project takes three years to generate a positive cash flow from energy savings, but the annual return on investment is then greater than 33 percent. In addition, the projects generate substantial employment opportunities in the construction industry.

These federal energy-efficiency programs make it possible for numerous state and local agencies to provide the technical and financial capacity for residential, commercial and industrial DSM programs. The nationwide efficiency effort has reduced national energy use; if the United States were still consuming energy as intensively as it did in 1973, it would have consumed approximately 116 quads in 1992 instead of the 85.5 quads actually consumed. This reduction in energy use represents a savings in energy costs to the American consumer of approximately $170 billion.[125] Federal energy-efficiency investments have been critical—and successful. Still greater financial and environmental gains could result from far-sighted national policies that bolster energy-efficiency and DSM budgets.

E. DSM Programs Could Become an Essential Utility Service in a Restructured Utility Industry

The utility industry is in the middle of a major restructuring. Adoption of the National Energy Policy Act of 1992 (EPAct)[126] has, by deregulating electricity sales among wholesale power buyers, stimulated a competitive wholesale power market while leaving end-user deregulation to the states.[127] Although the prospect of increased competition is leading some utilities to reduce or eliminate their DSM programs (because these programs often increase electricity prices), on a national level, DSM expenditures by utilities are projected to rise steadily through 1998.[128] Utilities are likely to refocus their DSM programs on customer service and customer productivity in an effort to retain market share and to gain new customers.[129]

The transition to competitive markets is a window of opportunity for improved energy efficiency and renewables development. The bottom line is that the new industry structure should be *more efficient*—both economically and in terms of environmental protection. Enhanced competition and environmental protection need not be enemies. Restructuring and re-regulation of the utility industry must incorporate efficiency and renewables development if the United States is to meet its international obligations to reduce the threat of global climate change.

F. Industrial Efficiency Services Will Exemplify Efficiency Programs in a Restructured Industry

Implementing effective industrial efficiency programs requires specialized expertise. By far, the greatest energy-efficiency savings are gleaned from changes in the industrial process. Process equipment and manufacturing configurations account for a whopping 90 percent of a typical industrial firm's overall energy use.

Many utilities hesitate to invest the time and effort required to locate trained assessors capable of evaluating different types of manufacturing operations. Utilities, however, have a compelling reason to target industry: industrial firms consume roughly 25 percent of all energy consumed in the United States.[130]

A number of case studies demonstrate that utility-industry partnerships can deliver efficiency improvements to the industrial process which save money, increase production, while reducing emissions. By bundling energy-efficiency *services* with power sales to their largest customers—services that include assistance with process manufacturing improvements that streamline operations and save on utility bills[131]—industries stay put, jobs remain in the local area, and utilities improve their customer relations. Industrial DSM programs will be a key component of utility restructuring. As the following examples attest, successful industrial DSM programs are already underway in several regions.

- ***Western Massachusetts Electric.*** Western Massachusetts Electric serves 810 industrial customers, which make up 27.1 percent of its load. The utility, strapped with high rates due to the cost of bringing a nuclear power plant on line, had, on average in 1992, the third-highest electrical rates in Massachusetts—8.9 cents per kilowatt-hour for industrial customers. But Western Massachusetts Electric now works directly with its industrial customers to find solutions to its high rates and to enhance customer competitiveness.[132]

For example, ***Greenfield Industries,*** a machine tool manufacturer and a Western Massachusetts Electric customer, had to cut costs and improve competitiveness if it was to remain in business. The utility stepped in with technical advice, and partnered with Greenfield to restructure the production line. The utility first offered to pay for a walk-through assessment of the plant, and subsequently subcontracted out a more detailed energy assessment, and it split the costs with Greenfield. Most of the measures recommended in the assessment were then implemented by the subcontractor, including new vacuum furnaces and monitoring plans. The utility paid an incentive rebate based on an avoided cost of 5 cents per kilowatt-hour. The rebate was enough to ensure that Greenfield's expenses for the retrofits paid for themselves from energy savings over just two years. Greenfield spent roughly $2 million on the new furnaces and plant reorganization, which included moving from a production process design that used 300,000 square feet across nine floors to one that utilized only 60,000 square feet an one floor. As a result of the improvements, Greenfield's production has risen 25 percent, market share has expanded, product quality has improved, and scrap rates have declined sharply. The firm estimates that 90 percent of its improved outlook is due to the process efficiency improvements—made possible by Western Massachusetts Electric. Greenfield's annual energy costs have fallen from $1 million to less than $400,000. The two new vacuum furnaces alone cut electricity consumption by 82 percent; the old furnaces consumed 1.8 million kilowatt-hours annually, while the new furnaces use 314,300 kilowatts per year, which means that carbon dioxide emissions decreased by 984 metric tons annually.[133]

The process efficiency improvements also eliminated manufacturing steps required by the old system, which necessitated the use of chlorofluorocarbons as well as cyanide. In fact, the utility partnership helped the company essentially eliminate hazardous waste generation. Productivity is up; managers have hired two new employees and expect to hire 12 to 16 more in the near future. In sum, the utility-industry partnership increased dramatically the facility's energy efficiency, reduced its generation of hazardous wastes, and improved productivity substantially. Equally important, employees are committed to continuous process improvements in production and in reducing waste. The change in employee outlook builds an enhanced pride in the company, and further spurs productivity.[134]

- ***Wisconsin Electric.*** Wisconsin Electric's "Smart Money for Business" program offers commercial and industrial customers zero-to-low interest loans or cash rebates for installing qualifying energy-efficiency measures. Prescriptive rebates are available for lighting, motor, HVAC, and refrigeration measures, while custom incentives are available for process-related improvements and are negotiated with each participant (between 15 and 30 percent of a custom project's total costs are typically covered by the incentive). Utility engineers communicate with process-level plant personnel, marketing the program to them; larger projects involve senior management of both the utility and customer simultaneously. More than half of all Wisconsin Electric's industrial customers have received rebates or loans through the Smart Money program. The utility has found that personal, one-on-one contact with the customer while providing technical expertise is essential to successful process-oriented programs. The program has reduced the utility's sales to industrial customers by 2.5 percent, at a levelized cost of 2.1 cents per kilowatt-hour saved. From 1987 through October 1993, Wisconsin Electric's cumulative electricity savings were 357,600 megawatt-hours, deferring 71.7 megawatts of capacity and cutting carbon dioxide emissions by 217,778 metric tons.[135]

- ***Bonneville Power Administration.*** Bonneville's decentralized, flexible "Energy $avings Plan" seeks to form partnerships with industrial customers and tailor process efficiency improvements to their needs. For example, the ***Holnam Company,*** a cement manufacturer in Seattle, sought to reduce its rising energy costs to compete in an increasingly competitive market for cement in the Pacific Northwest. Based on an assessment and plant evaluation sponsored by Bonneville, Holnam carried out four energy-efficiency projects, at a total cost of $248,232. Bonneville reimbursed the company $115,615 to account for the saved energy. The four projects, all of which targeted the production process, included kiln drive motors, kiln stack gas precipitators, cooler grate drive motors, and cooler fan motors. They will save a projected 1,782 megawatt-hours, or 3.4 kilowatt-hours per ton of cement, annually—improving productivity. These savings cut carbon dioxide emissions by 248 metric tons annually.[136] Most important, the partnership has established a flexible mechanism for future process efficiency improvements.

G. Conclusion

In the future, regulated local distribution companies are likely to continue to deliver energy-efficiency services to customers, as will a host of unregulated energy-service companies, equipment vendors, and power marketers. These changes in DSM-program orientation and delivery, however, are unlikely to alter significantly the rationale behind DSM programs. Regardless of the future structure of the utility industry, energy efficiency is an important asset: efficiency cuts customers' bills, reduces system costs, and cuts emissions.

III. Energy Use in Buildings: Progress in Efficiency Design, Retrofit Investments, and Equipment and Appliance Standards

The energy-efficiency of most of America's residences and commercial buildings could be substantially improved. In 1989, U.S. buildings consumed 36 percent of total U.S. energy at a cost of $200 billion.[137] That's more than what was consumed by transportation or industry. Residences spent $120 billion on energy bills, while commercial buildings (offices, stores, schools, hospitals) spent nearly $80 billion.[138] The energy consumed by U.S. buildings causes more than 450 million metric tons of annual carbon dioxide emissions—33 percent of the U.S. total and about 8 percent of *global* annual emissions.[139]

The United States could cut building energy consumption by 33 to 50 percent by the year 2015 if it invested in cost-effective, commercially available energy-saving technologies.[140] Substantial progress has been made. Energy-efficient building designs, retrofits, equipment, and appliances have *stabilized* energy intensity in the commercial sector,[141] and have *reduced* energy intensity in residences.[142]

The buildings sector, however, presents distinct policy challenges for capturing efficiency savings. Buildings occupants are often not owners—which undermines incentives to invest in efficiency and creates a market imperfection that is difficult to overcome.[143] Energy costs over a building's 50- to 70-year useful life are comparable to initial construction costs. Similarly, the life-cycle energy costs of equipment and appliances are often many times greater than their initial cost. Because markets focus more on the first costs than the full life-cycle costs of new buildings, retrofits, equipment, and appliances, public policy must correct these market failures through a combination of intelligent regulation and market incentives.

A. Energy-Efficient Design Is Demonstrating Dramatic Energy Savings

Energy decisions made when constructing buildings are long-lasting. The median lifetime for commercial buildings is between 50 and 70 years, far longer than most power plants.[144] The potential for savings is high. A reasonably-attainable 30 percent improvement in U.S. building efficiency would reduce energy bills by $75 billion annually in 15 years.[145]

1. Energy-Efficient Building Design Can Significantly Improve Worker Productivity

Numerous examples demonstrate that energy-efficient building and office design can significantly increase worker productivity. By improving lighting, heating, and cooling, workers can be made more comfortable and productive. An increase of 1 percent in productivity can provide savings to a company that exceed its entire energy bill.[146]

- ***Lockheed Missiles and Space Company.*** One of the most successful examples of efficient office-building design is Lockheed Missiles and Space Company's Building 157 in Sunnyvale, California.[147] The 600,000 square-foot office building, designed by the architectural firm Leo A. Daly, brings daylight deep into the building. A central atrium runs top to bottom; the building's 2,700 engineers and support staff consider it the building's most attractive feature. Exterior "light shelves" on the south facade operate as sunshades or as reflectors depending on the season; in summer, they bounce light onto the interior ceiling to maximize interior light, while in the winter, when the sun's angle is lower, they diffuse reflected light and reduce glare. The overall design separates ambient and task lighting, with daylight supplying most of the ambient lighting and task lighting fixtures supplementing each workstation. Continuously dimmable fluorescents with photocell sensors maintain a constant level of light automatically and save even more energy. The open office layout was designed to foster the interaction, and the comfort, of the engineers and staff. Employees rave about the building.

Daylighting has saved Lockheed about 75 percent on its lighting bill. Since daylight generates less heat than office lights, the design features cut peak air-conditioning substantially. Overall, the building runs with about half the energy costs of a typical building of similar size. Although the energy-efficient improvements added roughly $2 million to the building's $50 million capital costs, the energy savings are worth nearly $500,000 per year, and paid for themselves in a little more than four years.

More important, however, have been productivity improvements. Russell Robinson, manager of facility interior development, reports that productivity is up while absenteeism is down. Lockheed considers productivity data to be proprietary, but according to Don Aitken, chairman of the Department of Environmental Studies at nearby San Jose State University, "Lockheed moved a known population of workers into the building and absenteeism dropped 15 percent." Aitken led numerous tours of Building 157 after it opened, and was told by Lockheed officials that the reduced absenteeism paid 100 percent of the extra cost of the building in the first year. The architect, Lee Windheim, reports that Lockheed officials told him that productivity rose 15 percent on the first major contract done in the building. Apparently, top Lockheed officials told Aitken that they believe they won a very competitive $1.5 billion defense contract on the basis of their improved productivity—and that the profits from that contract alone paid for the entire building.[148]

• ***West Bend Mutual Insurance Company.*** Another example of improved productivity through energy-efficient design involves West Bend Mutual Insurance Company's new 150,000-square-foot headquarters in West Bend, Wisconsin. The building is the subject of one of the most carefully documented increases in productivity due to green design.[149]

The building incorporates a number of energy-saving design features, including an energy-efficient lighting system (including task lighting and occupancy sensors), efficient windows, shell insulation, and a more efficient heating, ventilation, and air-conditioning (HVAC) system. It uses a thermal-storage system that makes ice overnight to help cool the building during the day. Offices all have individual temperature and airflow controls. Perhaps the most innovative feature of the building is its "environmentally responsive workstations" (ERWs). Workers in open-office areas are given direct, individual control over temperature and airflow via radiant heaters and vents built directly into their furniture and controlled by a panel on their desks. The control panel also provides direct control of task lighting and white-noise levels. A motion sensor in each workstation turns the station off when the worker leaves the space and turns it back on when he or she returns.

West Bend Mutual Insurance's old building had used $2.16 of annual electricity costs per square foot. The annual electricity costs in the new building are $1.32 per square foot—a 39 percent reduction. Furthermore, the Rensselaer Polytechnic Institute (RPI) in Troy, New York conducted a detailed study of productivity in the old building in the 26 weeks before the move and in the new building for 24 weeks after the move. The conclusion of the RPI study: "The combined effect of the new building and ERWs produced a statistically significant median increase in productivity of approximately 16 percent over productivity in the old building."[150] Although a significant portion of the productivity increase derived from the ERWs, analysis shows that the majority of the productivity increase came from the building's energy-efficient design and systems.[151]

• ***Wal-Mart.*** Wal-Mart's prototype "Eco-Mart" in Lawrence, Kansas incorporates several energy-efficient design features that have produced several interesting surprises for Wal-Mart management. Although the Eco-Mart design includes a glass arch at the entrance for daylighting, an efficient lighting system, an HVAC system that utilizes ice-storage, and special light-monitoring skylights, it includes a design flaw: only half the store is daylit. Interestingly, departments located in the daylit half of the store are considerably more productive. Sales in the daylit areas are higher than any other department in the Eco-Mart. They are also significantly higher than the same departments in other Wal-Mart stores. Wal-Mart is implementing many of the Eco-Mart measures in new construction for other stores and is retrofitting already-built stores with various energy-efficiency measures.[152]

2. Building Codes Offer Substantial Energy Savings

Building codes are cutting U.S. energy consumption substantially. By the year 2000, improved residential and commercial building codes could cut electricity use by 14,000 gigawatt-hours,[153] reducing nationwide carbon dioxide emissions by some 8.86 million metric tons.[154]

Since the 1970s, private engineering societies, government agencies, and code official organizations have promulgated a number of model building codes that include energy-efficiency standards. The Energy Policy Act of 1992 requires states to adopt commercial building standards that meet or exceed the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) model standard for commercial buildings. However, states are only required to *consider* adopting such standards for *residential* buildings.[155] A considerable gap remains between what is possible for energy-efficient and economical building construction and actual practice.

The ASHRAE commercial building standards in effect nationally are expected to reduce energy bills by $2.1 billion annually by 2010.[156] Improved commercial building codes slated for adoption by ASHRAE could cut carbon dioxide emissions by 1 million metric tons per year by the year 2000 and 11.2 million metric tons annually by 2010.[157]

New homes have been built with designs that use half or less of the energy consumed in older homes. Every year, about 1 million new houses are built in America. Each represent a one-time opportunity: many energy efficiency designs and installations that are easy and inexpensive to include in new dwellings are difficult or expensive to add later as retrofits. Building codes are needed to "raise the floor" for energy efficiency in new homes.

• ***The Model Energy Code.*** Adoption of a widely accepted residential model energy standard—the Model Energy Code (MEC) of the Council of American Building Officials (CABO)—could save 500,000 megawatt-hours of energy in every year's new housing stock—enough to power another 65,000 to 70,000 single-family homes each year. Carbon dioxide emissions could be cut by 316,600 metric tons every year.[158] Cumulatively, the energy savings from ten years of housing starts could total 3.6 quads of energy over a 50-year span—which highlights the importance of capturing energy-efficiency opportunities at the time of construction.[159] If Congress would require adoption of the MEC at the state level, as well as improved code compliance and enforcement procedures,[160] carbon dioxide emissions could be cut by 600,000 metric tons by the year 2000 and 3.8 million metric tons by the year 2010.[161]

The MEC's added energy efficiency would be cost-effective. Although energy-efficiency installations can increase construction costs, energy savings would outweigh costs by 3-to-1 over a 30-year period. Every MEC home's annual energy bill would be reduced, on average, by $150, more than the average increase in mortgage payments of around $90. Thus, the actual "payback" to the average home buyer is almost immediate.[162]

B. Energy-Efficient Retrofits Are a Source of Energy Savings Waiting to be Mined

Retrofits of existing buildings are a source of efficiency waiting to be mined. Eighty percent of U.S. commercial buildings were built prior to 1979 and contain obsolete energy systems.[163] A full-scale retrofit generally calls for replacing lighting and HVAC system components, improving maintenance procedures, and installing computerized controls. Windows may be either replaced or coated with low-emissivity films, and sensors can be placed to monitor temperature and humidity, with the information fed into microcomputers to control the indoor climate.

1. Building Retrofits Cut Energy Bills While Improving Worker Comfort and Productivity

Energy-efficiency retrofits for existing buildings and residences have attractive economic returns. For example, a three-year payback, which is typical in lighting retrofits, is an internal rate of return of 33 percent—generally superior to the results of financial managers for personal investments. Retrofits typically cut energy use by 50 cents or more per square foot of commercial space, a significant reduction in overhead.[164]

The greatest gains, however, are found—somewhat surprisingly—in improved worker productivity that often results from efficiency improvements.[165] Because labor costs dwarf energy costs per square foot, productivity gains often are the prime motivator for businesses to improve energy efficiency.[166] In the following examples, companies set out to cut energy and maintenance expenditures through energy-efficiency retrofits. Gains in worker productivity were often an unintended, added benefit of the energy efficiency investments.[167]

• ***Main Post Office, Reno, Nevada.*** In 1986, mail sorters at the Main Post Office in Reno, Nevada became the most productive in the western region of the United States. A $300,000 lighting retrofit, which included a lowered ceiling that made the room easier to heat and cool, boosted productivity more than 6 percent annually. The rate of sorting errors by machine operators dropped to 0.1 percent —the lowest error rate in the western region. The annual energy and maintenance savings came to about $50,000—a six-year payback. The productivity gains, however, were worth $400,000 to $500,000 per year, and paid for the entire renovation in less than a year.[168]

• *DOE's James Forrestal Building.* The U.S. government spends $9 billion each year on energy for federal buildings, operations, and employee transport. Federal agencies are required by law to reduce their energy use by 30 percent in the next decade (from 1985 consumption levels).[169] The goal is to save $400 million annually by the year 2000, and $1 billion a year by 2005. The DOE has made strides toward this goal, starting with its own headquarters, the James Forrestal Building in Washington, D.C. Lighting upgrades in 1994 cut energy bills by two-thirds. Because the retrofits produce higher quality light, worker comfort and productivity has increased. The cost of the project, $1.36 million, was paid for with a ***Potomac Electric Power Company*** utility rebate plus private-sector financing from an energy-service company (ESCo). The ESCo will recover its investment from the anticipated 63 percent savings in lighting consumption. The reduced electricity demand cuts pollution emissions in the local utility service area by 27 metric tons of sulfur dioxide, 14 metric tons of nitrous oxide, and more than 3,600 metric tons of carbon dioxide.[170]

• *City of Phoenix's Energy Management Program.* Municipalities and school districts have improved productivity through energy-efficiency retrofits. The Energy Management Program for the city of Phoenix, Arizona installed energy-efficiency measures in 300 municipal buildings—including an airport, water and waste treatment plants, offices, libraries, and fire and police stations—saving the city $22.8 million over 16 years, plus far greater savings in worker productivity improvements. Energy savings over this period exceeded 290,000 megawatt hours, cutting carbon dioxide emissions by approximately 105,000 metric tons.[171]

• *EPA's Energy Star Buildings Program.* In April 1995, EPA launched a comprehensive, nationwide strategy for maximizing energy-efficiency in existing buildings. EPA's "Energy Star Buildings" program is underway in twenty-four "showcase" buildings nationwide, and includes buildings owned by ***Honeywell, Inc., J.C. Penney, Mobil Corporation, Target Stores, The Washington Times,*** and others.

The program involves a five-stage upgrade strategy that capitalizes on system interactions to maximize energy savings at minimum cost. After upgrading to energy-efficient lighting (stage 1), participants tune up building systems (stage 2) and reduce heating and cooling loads (stage 3). Participants then improve fans and air-handling systems (state 4) and improve heating and cooling equipment (stage 5). Upgrades are staged so that heating and cooling loads are reduced before major HVAC equipment upgrades are initiated. This staged approach provides immediate energy cost savings and ensures proper load matching when upgrading major equipment in the latter stages of the strategy.

Results in the showcase buildings have been impressive. On average, participants are reducing their energy use by 35 percent and earning a 58 percent return on their investment. By the year 2000, the Energy Star Buildings program could lower annual U.S. buildings energy expenditures from today's $70 billion annually to about $42 billion.[172]

2. Lighting Retrofits Cut Error Rates and Improve Productivity

Lighting accounts for 19 percent of all electricity sold in the United States.[173] Every kilowatt-hour of lighting not used prevents emissions of 5.8 grams of sulfur dioxide, 2.5 grams of nitrogen oxides, and 1.5 pounds of carbon dioxide.[174] The best light bulbs on the market use only a quarter as much energy as conventional incandescent light bulbs and last ten times longer, preventing the burning of up to 400 pounds of coal, and saving consumers a net $35 on their electricity bills over the life of the improved bulb.

If energy-efficient lighting were installed everywhere profitable, America's demand for electricity would drop by more than 10 percent. This would result in annual emission reductions of 1.3 million metric tons of sulfur dioxide, 600,000 metric tons of nitrogen oxides, and 202 million metric tons of carbon dioxide. Those reductions would be equivalent to taking 44.5 million cars off the road,[175] and represent 12 percent of all U.S. utility emissions.[176]

• *EPA's Green Lights Program.* Although lighting represents only about 10 percent of the available electricity savings potential in the U.S. economy, lighting represents one of the easiest ways to save electricity.[177] The Environmental Protection Agency's "Green Lights" Program has brought together more than 1,600 organizations[178] to upgrade their lighting with state-of-the-art technologies. In 1994, Green Lights participants saved more than 1 million megawatt-hours of electricity, which reduced electricity bills by more than $92 million[179] and cut carbon dioxide emissions by approximately 633,200 metric tons.[180] The typical Green Lights upgrade yields an after-tax internal rate of return of 20 to 40 percent. Unanticipated benefits often include increased employee productivity and morale improvements from better lighting quality. Full implementation of Green Lights upgrades by current participants could save $15.8 billion and 12.2 million megawatt-hours of electricity annually, while cutting carbon dioxide emissions by more than 7.7 million metric tons per year.[181] If that $15.8 billion were reinvested in jobs and enhanced productivity, by the year 2000, Green Lights could result in more than 220,000 new jobs.[182]

- *Lawrence Berkeley National Laboratory.* Since the mid-1970s, the DOE has invested some $70 million at Lawrence Berkeley National Laboratory (LBNL) for research and development of advanced energy-efficient building technologies, software, and standards. That investment has helped spawn a $2.4 billion U.S. market for key products—including energy-efficient lighting.

Lighting costs U.S. businesses and consumers nearly $40 billion each year. The strategic use of federal research dollars can trim billions from this annual bill. LBNL's early work on the electronic ballast illustrates the potential payoff from lighting research and working with industry.

The electronic ballast has developed from a laboratory curiosity to a highly successful energy-efficient lighting technology. By 1993, electronic ballasts had captured 23 percent of total ballast sales. They will likely replace magnetic ballasts in more than 75 percent of applications by 2015 because of utility and other incentive programs and federal programs and standards. The federal investment in electronic ballast research and development is about $3 million. Cumulative energy savings attributable to electronic ballasts from 1988 to 1993 alone were $400 million. Businesses and consumers will ultimately save a net $700 million from electronic ballasts installed through 1993, which could grow to $13 billion for technologies installed through the year 2015. By 2015, electronic ballast technology could avoid 142,400 metric tons of sulfur dioxide, 130,600 metric tons of nitrogen oxides, and 66.2 million metric tons of carbon dioxide.[183]

- *Boeing.* Substantial inroads have been made in cutting lighting electricity demand. For example, Boeing, headquartered in Renton, Washington, has been an EPA Green Lights participant. Lighting upgrades have cut electricity use by 25 to 90 percent in several million square feet of its facilities, with a 53 percent annual return on investment. Boeing's upgrades have saved 130,000 megawatt-hours, have paid for themselves in just two years, and have cut carbon dioxide emissions by 18,070 metric tons per year. Other air pollutants have also been reduced, including 4,536 metric tons of sulfur dioxide and 1,815 metric tons of nitrogen oxides each year. The new lighting has improved workers' abilities to detect defects by 20 percent. The savings from catching errors early, according to Lawrence Friedman, Boeing's conservation manager, while difficult to measure, are estimated to exceed greatly the cost of the energy-efficient upgrades.[184]

- *Pennsylvania Power & Light.* Pennsylvania Power & Light's drafting engineers had been working in a 12,775-square-foot room prone to "veiling reflections," a form of indirect glare. A lighting upgrade—consisting of high-efficiency lamps and ballasts fitted with parabolic louvers to reduce glare—in a 2,275-square-foot portion of the shop floor brought impressive results. Building superintendent Russell Allen notes, "Generally speaking ... we converted from general lighting to task lighting. As a result, more of the light is directed specifically to work areas and less is applied to circulation areas, creating more variance in lighting levels which upgrades the appearance of the space." The total net cost of the lighting upgrade was $8,362. Energy use dropped 69 percent, and annual operating costs fell 73 percent from $2,800 to $765. With these savings, the investment would have paid for itself in 4.1 years, a 24-percent return. But the resulting 13.2 percent boost in productivity, worth $42,240 a year, turned a 24 percent return on investment into a 540 percent return with payback in just 69 days. Absenteeism and error rates dropped and morale rose, changes worth at least another $50,000 per year. All told, the return on investment exceeded 1,000 percent.[185]

• *AT&T.* AT&T in Columbus, Ohio slashed its energy costs by $4.5 million over 14 years by installing state-of-the-art metal halide light bulbs, improving insulation, and installing variable-speed drives on heating, ventilation, and air-conditioning fans.[186] The light bulb retrofits alone saved roughly 1,000 megawatt-hours of electricity per year—which slashed electricity bills 50 percent—while increasing light levels 70 percent. Workers in assembly areas, where small parts are handled, reported that they can see better now that old-style fluorescent lighting has been replaced with metal halide bulbs. Assembly errors have dropped, resulting in a marked improvement in productivity. The lighting retrofits alone cut carbon dioxide emissions by 820 metric tons annually. [187]

• *Hyde Tools.* Hyde Tools, a Massachusetts-based manufacturer of cutting blades, installed a lighting upgrade of sodium-vapor and metal-halide bulbs in the early 1990s. The retrofit cost $98,000 (including labor), with $48,000 of that covered by the local utility. Annual energy savings came to $48,000, yielding a payback of about one year. Substantial productivity improvements resulted unexpectedly. Doug DeVries, the company's purchasing manager, initially installed the upgrade in only a small portion of the factory floor. At first, several workers complained because the new lights cast an orange hue. After six months, he gave workers the option of restoring the original lighting on the principle that no amount of energy saved would be worth making his operators dissatisfied. But according to DeVries, "When we experimented by turning the old fluorescent lights back on after six months, there was a near riot of disapproval." The new lights had made it possible to see tiny specks of dirt on each blade during their manufacture. Unless detected, the dirt caused product defects. With the new lighting, DeVries says, "The quality of work improved significantly because we could see things we couldn't see before." DeVries estimates that the improved quality was worth another $25,000 a year to the company. DeVries notes that every dollar saved on the shop floor is worth $10 in direct sales—and thus the improved quality from the efficient lighting was the equivalent of a $250,000 increase in sales.[188]

• *United Airlines.* The United Airlines Maintenance Operations Center at San Francisco International Airport could save an estimated $100,000 annually due to a lighting retrofit recently completed by Parke Industries, Inc. United wanted to improve productivity in an important maintenance and repair area by enhancing the quality of light. Workers in this area regularly service aircraft, parts and components for the airline's entire fleet flying both domestic and international routes. The lighting project is expected to cut 1,022 megawatt-hours of electricity annually, saving $51,000 off annual electric bills—about half the original $100,000 annual operating cost. The project payback is 1.09 years. Additional benefits include another $48,000 in savings from reduced maintenance requirements. Carbon dioxide emissions could be cut by 350 metric tons each year.[189]

• *The World Trade Center.* New York's World Trade Center is receiving a $1,826,000 lighting retrofit. The *New York Power Authority* High-Efficiency Light Program is providing an $834,000 cash incentive and is offering a shared savings deal on the $991,000 balance. Yearly demand and consumption of electricity will be reduced by approximately 828 kilowatts and 5,121 megawatt-hours, resulting in an annual savings of nearly $330,000 while reducing annual carbon dioxide emissions by 2,406 metric tons.[190]

• *Lockheed Martin Defense Systems.* Lockheed Martin Defense Systems in Pittsfield, Massachusetts upgraded more than 8,000 assorted fluorescent fixtures to high-efficiency electronic ballasts and energy-efficient T-8 lamps, saving 3,400 megawatt-hours of electricity per year and reducing annual energy bills by $188,100 (a 113 percent internal rate of return). Carbon dioxide emissions were reduced by 2,250 metric tons per year, which is equivalent to taking 496 cars off the road each year.[191]

• *Ashton Elementary School.* Ashton Elementary School in Sarasota, Florida retrofitted its lighting from 4,444 T-12s and 20 incandescent lamps to 2,222 T-8s and 20 compact twin-tube lamps, which improved the quality of classroom light while reducing electricity consumption by 246 megawatt-hours per year at a savings of $17,236—an annual internal rate of return of 50 percent. Carbon dioxide emissions were cut by 144 metric tons annually, equivalent to taking 32 cars off the road per year.[192]

• ***Shell Oil.*** Shell Oil implemented a lighting upgrade at its Anacortes, Washington refinery, replacing 7,730 150-watt incandescent lamps with 7,520 70-watt high pressure sodiums and 240 T-8 lamps. The retrofit cut electricity demand by 1,803 megawatt-hours per year, saving $127,346 in energy costs—a 25.5 percent internal rate of return. Greater efficiency from the lighting upgrade reduced annual carbon dioxide emissions by 250 metric tons, equivalent to taking 55 cars off the road each year.[193]

• ***University of California at Berkeley.*** University of California at Berkeley's five-year, $6 million lighting upgrade project renovated the lighting in 60 campus buildings by installing 91,000 high-efficiency ballasts, 18,000 reflectors, and 3,000 occupancy sensors. Electricity saved amounted to 12,116 megawatt-hours each year, at an energy cost savings of $909,000 annually—a 20 percent internal rate of return. Annual carbon dioxide emissions were reduced by 4,156 metric tons, equivalent to taking 915 cars off the road each year.[194]

• ***Tennessee Valley Authority.*** The Tennessee Valley Authority set an example for other public agencies by replacing 524 incandescent fixtures with compact fluorescents and 190 incandescent exit signs with LED exit signs at its Knoxville Office Complex. TVA also replaced 9,400 old fluorescent fixtures with T-8 lamps, electronic ballasts, and parabolic lenses and installed 1,200 occupancy sensors to control lighting. The upgrade cut TVA's electricity demand by 3,100 megawatt-hours, saving $210,000 each year while reducing annual carbon dioxide emissions by 1,879 metric tons—equivalent to removing 414 cars from the road each year.[195]

• ***Nike, Inc.*** Nike upgraded 1,545 T-12 lamps to 1,545 8-foot T-8 lamps, all with electronic ballasts, at its Western Division Distribution Center in Wilsonville, Oregon. It also upgraded 44 exit signs from 20-watt incandescent lamps to 2-watt LEDs. After the upgrade, Nike found it was spending half the amount on energy while getting twice the lighting level. Electricity demand dropped by 331 megawatt-hours per year, saving $16,553. Annual pollution reduction benefits included 22 metric tons of sulfur dioxide, 13 metric tons of nitrogen oxides, and 35 metric tons of carbon dioxide. Said Nike, "There are always ways to *Just Do It* better."[196]

• ***Compaq Computer Corporation.*** Employees at Compaq Computer's Houston, Texas headquarters were pleased with a lighting upgrade that reduced both glare and reflections, while saving money and reducing the company's environmental impact. The company retrofitted older fixtures with two 40-watt enhanced T-10, 3,700 lumens, 80 CRI with 24,000-hour life. Lighting energy usage fell 39 percent. Overall electricity consumption dropped by 1,307 megawatt-hours per year, saving $83,493 annually in energy costs. Annual pollution reduction benefits included 193 metric tons of sulfur dioxide, 120 metric tons of nitrogen oxides, and 920 metric tons of carbon dioxide emissions.[197]

• ***Amoco Oil.*** In early 1993, Amoco decided it would install 10,300 T-8 lamps, 105 energy-efficient exit sign lamps, and 500 occupancy sensors in its Tulsa Research Center in Tulsa, Oklahoma. Energy savings totaled 1,197 megawatt-hours per year, a cost savings of $124,883 annually. Pollution reduction benefits include 34 metric tons of sulfur dioxide, 46 metric tons of nitrogen oxides, and 907 metric tons of carbon dioxide each year.[198]

• ***The Washington Times.*** The Washington Times upgraded its headquarters facility in Washington, D.C. with 6,360 T-8's, 1,151 compact fluorescents, 145 occupancy sensors, 409 halogen PAR lamps, and 153 LED exit signs. According to one receptionist, "I no longer feel heat on my head all day long. The light bulbs . . . are much cooler and give off better light than before. These lights have cured my headaches." Electricity savings annually amounted to 1,085 megawatt-hours and $72,810 per year. Annual pollution-reduction benefits included 244 metric tons of sulfur dioxide, 77 metric tons of nitrogen oxides, and 1,293 metric tons of carbon dioxide.[199]

• ***Bell Atlantic.*** Bell Atlantic retrofitted all fluorescent fixtures at its Data Center in Richmond, Virginia with T-8's and electronic ballasts, and installed a variable voltage dimming system to reduce glare and enable a constant light output. Air-conditioning energy outlays dropped by 273 megawatt-hours due to the new, cooler lighting. Total electricity usage fell by 1,600 megawatt-hours, saving $109,000 each year. Annual pollution reduction benefits include 443 metric tons of sulfur dioxide, 141 metric tons of nitrogen oxides, and 803 metric tons of carbon dioxide emissions.[200]

• ***McDonald's Corporation.*** McDonald's Corporation is engaged in a nationwide effort to upgrade existing 4-lamp fluorescent fixtures with T-8 lamps and electronic ballasts. The average results for one McDonald's restaurant, based on a sample of more than 200 stores in the northeastern United States, include electricity reductions of 30 megawatt-hours at a savings of $2,260 per year—reflecting a 38 percent internal rate of return. Carbon dioxide reductions total 19 metric tons per store annually, equivalent to taking 4 cars off the road per year. In the words of Joe Megacz, corporate utilities manager, "The energy savings numbers per store may be modest, but when you multiply them by the 1,500 company-owned restaurants we have committed to the Green Lights program, the total becomes significant."[201]

• ***Provo, Utah's City Hall.*** The city of Provo, Utah—which developed the first prototype hydrogen-powered mass-transit bus back in 1974—upgraded its City Hall with a combination of T-8s, compact fluorescents, and high-pressure sodium lamps. The result saves 709 megawatt-hours of electricity each year and reduces the city's electricity cost $36,678 annually, reflecting a 22 percent internal rate of return. The lessened electricity demand prevents 640 metric tons of annual carbon dioxide emissions. In the words of Alan Dewitt, Provo facility manager, "[w]e are committed to energy efficiency as a *city*. By making our buildings more efficient, we have become a model for citizens throughout the community."[202]

• ***Marriott Marquis Hotel.*** The New York Marriott Marquis Hotel has extensively upgraded its 1,825,726-square-foot facility. The upgrade included the addition of an Energy Management System. Guest room upgrades alone replaced 10,009 incandescent lamps with compact quad-tube lamps. Total annual electricity reductions were 2,556 megawatt-hours, which saves $190,033 each year—an internal rate of return of 100 percent. Carbon dioxide emissions were cut by 1,201 metric tons each year, equivalent to taking 264 cars off the road per year. According to Ed Pietzak, director of engineering, "The hotel used less electricity in 1994 than it did in 1986, despite the guest room occupancy rates *increasing* from 64.8 percent to over 90 percent... The experience of the hotel shows that even with relatively new facilities and increasing occupancy rates, significant savings can be achieved."[203]

• ***Longs Drug Stores.*** Longs Drug Stores in Hilo, Hawaii upgraded from T-12s and incandescents to T-8s and compact twin-tube lamps. The store's management also installed occupancy sensors and reflectors. Electricity usage has dropped by 31,974 megawatt-hours per year, saving $3,453,166 annually, which represents an 83 percent internal rate of return. Annual carbon dioxide emissions have been reduced by 21,966 metric tons. David Alexander, facilities manager, says, "It became apparent after our upgrades that we not only saved the expected energy, but also that the visual acuity of our customers and employees was dramatically improved. After upgrading our store's lighting, we learned that saving energy in lighting does not have to mean working in a cave."[204]

• ***U.S.X. Corporation/U.S. Steel Group.*** U.S.X. Corporation/U.S. Steel Group listened to employees' suggestions to upgrade to section lighting and timers in the company's Caster Spares Building in Gary, Indiana. The workers designed a lighting system that saves the Gary plant $120,892 annually while cutting electricity usage by 2,628 megawatt-hours per year. The upgrade changed 748 400-watt mercury vapor lamps to 403 600-watt high pressure sodium lamps, which operate 87 percent fewer hours per year under timed switching devices. Annual pollution reduction benefits include 784 metric tons of sulfur dioxide, 264 metric tons of nitrogen oxides, and 2,588 metric tons of carbon dioxide. Tim Briney, plant coordinator at the Gary plant, had this to say: "We listen to the workers in our facilities. And they wanted to upgrade their lighting."[205]

• ***The County of San Diego.*** San Diego County, California sought to upgrade lighting in as many of its 610 buildings as possible. In the words of Tom DuMont, deputy director of facility services, "Our experience has demonstrated that the commitment and involvement of directors and top managers provide the momentum to start and maintain an aggressive, major relighting program, and to ensure that the financial benefits are well understood by executive, financial, and administrative officials." At its Operations Center Annex, the county upgraded a combination of T-12s and incandescent lamps to T-8s and compact quad-tubes, saving 1,063 megawatt-hours and $99,009 annually. Pollution-reduction benefits include 22 metric tons of sulfur dioxide, 30 metric tons of nitrogen oxides, and 365 metric tons of carbon dioxide emissions annually.[206]

• ***Massachusetts Institute of Technology.*** The Massachusetts Institute of Technology in Cambridge, Massachusetts upgraded campus lighting with approximately 225,000 T-8 lamps, 100,000 electronic ballasts, 3,000 reflectors and 2,500 new fixtures. Electricity demand dropped by 12,278 megawatt-hours per year, saving $982,241 annually—a 13 percent internal rate of return. William Wohlfarth, P.E., senior electrical engineer for the school, noted that the upgrade was "well received by facility users. The improved color rendition was observed immediately, and people noted better depth perception and clearer, cleaner spaces. My advice to other organizations is to spend time obtaining good initial surveys and accurate run hours. Also, you should standardize on upgrade materials as much as practical, and negotiate large quantity material prices." MIT's upgrade avoids 8,128 metric tons of carbon dioxide emissions annually, equivalent to taking 1,790 cars off the road each year.[207]

• ***Johnson & Johnson.*** At Johnson & Johnson's McNeil Consumer Products Company in Fort Washington, Pennsylvania, nearly all buildings received lighting upgrades, including buildings performing such diverse functions as manufacturing, product packaging, administration, research, warehousing, food service, and child development. The light quality has greatly improved and maintenance has been reduced. By converting all 6,000 inefficient fluorescents to T-8s and T-10s, all incandescents to compact fluorescents, and all exit signs to LED or compact fluorescents, the facility is saving 1,373 megawatt-hours per year and cutting its energy bills by $107,574 annually. Pollution reduction benefits include 8 metric tons of sulfur dioxide, 3.7 metric tons of nitrogen oxides, and 800 metric tons of carbon dioxide each year. Spokesman Mike Vlasic notes that "with the money we are saving . . . we have expanded into other energy saving products—such as motion sensors and exit lights—and enhanced our energy management system."[208]

3. Home Energy Rating Systems (HERS) Provide Important Consumer Information

Every year, 3.5 million homes in America change hands. Every transfer offers an opportunity to retrofit homes with energy-efficiency measures. When buying a home, consumers typically only have enough information to base their decision on the home's first costs. But the life-cycle energy costs of a home, like a car or appliance, are important values that make a substantial difference in the real cost—and value—of a home.

• ***DOE's Five-Star Rating Program.*** The U.S. DOE has developed a uniform home energy rating system that evaluates the efficiency of residences on a 100-point scale. The most efficient house receives 100 points ("five stars plus"), indicating a home that is roughly two times as efficient as one built to the specifications of the 1993 Model Energy Code.[209] In mid-1995, DOE proposed the program as a national standard, with voluntary adoption left to the states. States should be encouraged to implement the program, which will offer buyers essential information about the life-cycle energy costs of a potential home purchase.

Uniform Home Energy Rating Systems (HERS), nationwide, will remove market barriers to financing for energy-efficiency investments. The real estate industry, and most consumers, fail to recognize the life-cycle market value of efficiency investments. Lenders are generally unwilling to loan more dollars for more efficient houses, even though those households have greater disposable income due to lower energy bills. Uniform efficiency ratings will help standardize the real estate efficiency market, enabling lenders and utilities to expand energy loan programs and increase consumer demand.[210]

• ***Energy Rated Homes of America.*** The private sector has also taken on HERS. "Energy Rated Homes of America" also uses a 100-point scale and provides an "as-is" rating for each home it evaluates.[211] An "improvement-options" rating is also provided, which indicates how the home would rate, and the potential savings, if fully detailed retrofit measures were installed. Thus the process of rating a home not only provides a score, but provides the home owner with cost-effective, suggested improvements. The funds necessary to carry out these improvements can be added to mortgages—discussed below—allowing inefficient homes to be upgraded and the cost of improvements financed over the life of the loan.[212]

• ***The Austin, Texas "Energy Star Program."*** Austin's Energy Star Program is a similar new-home HERS program. The rating compares a particular energy-efficient home to the same home if it were built to minimum code standards. A one-star home[213] saves approximately 6 percent more energy than the base (code-built) home; a two-star home[214] saves about 15 percent; and a three-star home[215] represents more than 23 percent energy savings. Austin has marketed the Energy Star Program especially toward volume builders, who typically are conscious of small incremental cost increases per unit and historically have been less inclined to meet efficiency levels much above code requirements. Austin has been able to get more than 40 builders to join the Energy Star Program—a majority of the builders in the Austin area. The builders have become so actively involved in the program that, according to Doug Seiter, Energy Star Program manager for the city, they are "changing their design plans just to get better ratings. They've been joining because it makes them competitive."[216] In the 12 months preceding October 1, 1990, the program had given Energy Star ratings to 622 homes, representing 50 to 60 percent of that year's new residential building stock. These homes saved more than 1 million kilowatt-hours that year—enough electricity to serve more than 100 homes for a year. Projected electricity savings are estimated to be $143,060, an average of $230 per home. Just these 622 homes saved 704 metric tons of carbon dioxide emissions during 1990.[217]

4. Energy Efficient Mortgages (EEMs) Can Provide Necessary Retrofit Financing

The Federal Housing Administration, Fannie Mae, Freddie Mac, various lenders, and numerous utilities have introduced new financing products for energy-efficiency upgrades. Home buyers are being encouraged to install efficiency improvements at the time of purchase through Energy Efficient Mortgages (EEMs)—which provide financing for efficiency upgrades as part of a home mortgage package. EEMs allow home buyers to automatically qualify for a larger mortgage to pay for efficiency improvements—improvements which then more than pay for the added cost of the mortgage through energy savings. Lenders provide EEMS under the rationale that the mortgagee will have greater disposable income from savings on utility bills and can therefore afford a greater monthly mortgage payment.[218]

• ***The Federal Housing Administration.*** The Federal Housing Administration (FHA) is authorized by the Energy Policy Act of 1992 to offer up to $8,000 above the qualifying loan amount for cost-effective[219] efficiency retrofit measures at the time of home resale. In October 1995, the FHA announced that it is expanding its EEM program nationwide. The FHA EEM will apply not only to retrofits but also to new construction.[220] A borrower can finance through the mortgage 100 percent of the cost of eligible energy-efficient improvements—which may include energy-saving equipment as well as active and passive solar technologies—without an appraisal of the energy improvements and without further credit qualification of the borrower.[221]

• ***Fannie Mae and Freddie Mac.*** In Colorado, Fannie Mae and Freddie Mac have a loan program that allows borrowers to finance energy upgrades in both new homes and resales as long as the increase is less than or equal to the present-value calculation of the rated energy savings. Both Fannie Mae and Freddie Mac have expressed an interest in taking the program nationwide. Under Fannie Mae's Community Home Buyers Program, purchasers with incomes at or below the national median can finance efficiency upgrades with a 3 percent down payment. Freddie Mac has a similar program known as the Affordable Gold Program that reduces the cash required for the down payment. These programs qualify low or median income home buyers for energy-efficient homes using cash from utility rebate programs as part of their down payment.[222]

• ***Pacific Gas and Electric.*** In California, Pacific Gas and Electric has teamed with three lenders to automatically qualify buyers for an additional 10 percent mortgage, at below-market interest rates, for homes that are rated 10 to 25 percent more efficient than the California state energy code. Loan demand has exceeded all expectations. The lenders involved are now marketing these new incentives nationwide to utilities and ratings organizations interested in promoting energy-efficiency financing.[223]

Fannie Mae is pilot testing an unsecured home-improvement loan at below-market interest for up to $15,000 with the same California utility. This energy loan program is operated with a utility partner and a third-party consumer loan originator. If successful, Fannie Mae says it will take the program nationwide.[224]

5. Energy Services Companies Provide Retrofit Services With Immediate Energy Savings

Efforts to improve energy efficiency in buildings are often obstructed by the divergent priorities and incentives of the building industry. Lack of coordination between architects, building engineers and subcontractors, lenders, owners, tenants, and the operations and maintenance staffs of large commercial buildings often results in a failure to capture potential energy efficiency savings.[225]

Energy Services Companies (ESCos) are in the business of designing and installing energy-efficiency systems in buildings, typically on a performance contract basis. Performance contracts allow businesses and building owners to upgrade their facilities without sacrificing scarce financial resources up front. ESCo performance contracts guarantee a positive financial return from efficiency upgrades throughout the contract term. ESCos often bundle their services with private bank financing packages that provide a net positive cash flow from energy savings from day one of efficiency installations.

ESCos typically conduct an initial audit of a building, and then implement a multi-stage retrofit involving lighting upgrades, automation and control systems, temperature control systems, improved HVAC systems, building envelope and windows upgrades, and microprocessor-based energy management control systems for monitoring overall system efficiency. Additional ESCo services include indoor air quality diagnostics, chlorofluorocarbon (CFC) replacement, maintenance of equipment and controls, and on-site training of employees in order to optimize building performance and energy savings.[226]

- ***Honeywell, Inc.*** Honeywell, headquartered in Minneapolis, Minnesota, is the largest U.S. ESCo. Honeywell has retrofitted buildings and facilities throughout the U.S. with energy-efficiency technologies and processes, including federal, state and local governments, schools, hospitals, commercial buildings and industries. Honeywell uses performance contracting, and bundles its services with private bank financing that guarantees a neutral or positive cash flow from efficiency upgrades. Most often, actual energy savings far exceed the performance guarantee, with all additional energy savings accruing to the customer.

In 1990, Honeywell contracted with the City of Seattle, Washington to install efficiency upgrades in the Seattle Municipal Building. Honeywell replaced old lighting with new electronic ballasts and T-8 fluorescent lamps. Automated centralized lighting controls and occupancy sensors reduced the hourly energy used for lighting from 400 kilowatt-hours to 224 kilowatt-hours. To improve poor indoor air quality, Honeywell installed a new high-efficiency air filtration system and new fan coil units. In the first two years, the upgrades cut building energy use by 2,483 megawatt-hours—an energy savings of 62 percent. These savings avoided 345 metric tons of carbon dioxide emissions annually, equivalent to removing 76 cars from the road.[227]

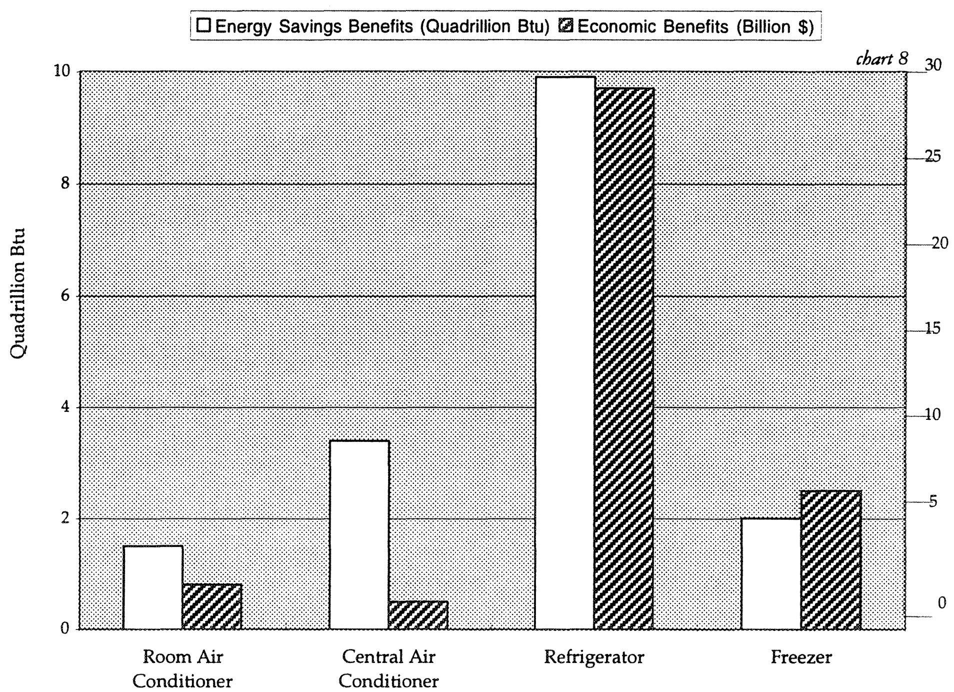
ESCos will play an increasing role in the future, both in the buildings sector and in a restructured utility industry, because of their ability to package capital with design expertise, serving to improve their clients' bottom line. Government facilities, private businesses, public housing and potentially private residences can benefit from ESCo services.

C. Energy-Efficient Appliances and Equipment Provide Significant Energy Savings

During the late 1970s and early 1980s, a number of states established efficiency standards for major home appliances, and appliance manufacturers petitioned the federal government to establish uniform preemptive national standards. These were enacted as the National Appliance Energy Conservation Act of 1987. There are now national efficiency standards for most categories of home appliances and equipment. The U.S. DOE periodically reviews and updates these standards. Although efficiency measures add a small extra cost to products, the efficiency standards are set at levels where the extra costs are rapidly offset by energy savings.[228]

Residential appliance standards alone are already saving consumers $1.9 billion annually, and ultimately will save consumers $132 billion net over the lifetime of products purchased by 2030, providing a ratio of total benefits to costs of 3-to-1.[229] Past and necessary future appliance and equipment standards could cut residential electricity use 7 percent by the year 2015, saving about 80,000 gigawatt-hours and 21,000 megawatts of capacity annually[230]—which represents approximately 50.6 million metric tons of carbon dioxide reductions per year.[231]

Life-Cycle Energy and Economic Benefits of Selected Appliance Standards



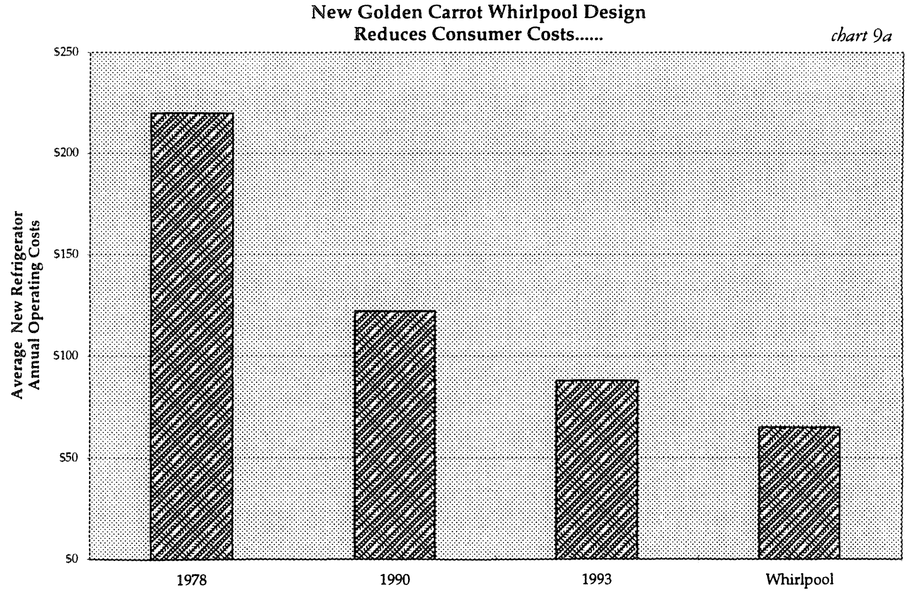
Source: Oak Ridge National Laboratory

1. Whirlpool's "Golden Carrot"™ Super-Efficient Refrigerator

One of the most creative and impressive new technology-forcing incentives is the "Golden Carrot"™ Super-Efficient Refrigerator program.[232] Refrigerators consume 20 percent of all residential electricity, and average about 685 kilowatt-hours per refrigerator each year.[233] To encourage manufacturers to develop and market refrigerator-freezers that are substantially more efficient than the 1993 standards, and also to influence the next round of federal standards, a group of electric utilities formed a consortium—the Super Efficient Refrigerator Program, Inc. (SERP).[234] In July 1992, SERP issued a Request for Proposals to refrigerator manufacturers asking them to design, manufacture, and sell the most energy-efficient refrigerator possible—while competing for a $30 million pot of incentive money. The manufacturer who promised the most energy savings at the lowest cost per kilowatt-hour saved was to win the entire pot (provided that the manufacturer can sell enough qualifying models within the service areas of the participating utilities). To be eligible, bids had to be for CFC-free designs. In October 1992, SERP received fourteen bids, including a number of bids from major manufacturers. In December 1992, it selected two semi-finalists—***Frigidaire*** and ***Whirlpool***. These manufacturers then built prototype units and submitted them to SERP for testing. Both prototypes used roughly 40 percent less energy than required under the 1993 federal efficiency standards. SERP selected a single winner in June 1993—Whirlpool. The $30 million prize will be paid as the efficient Whirlpool refrigerators are delivered to retail stores within the service areas of participating utilities.[235]

Energy savings from the Golden Carrot™ program are substantial. About 25,000 SERP refrigerators were sold in 1994, providing savings of 7,100 megawatt-hours of energy and 1.6 megawatts of capacity—and cutting carbon dioxide emissions by about 4,495 metric tons. Over the life-cycle of those 25,000 refrigerators, 135,375

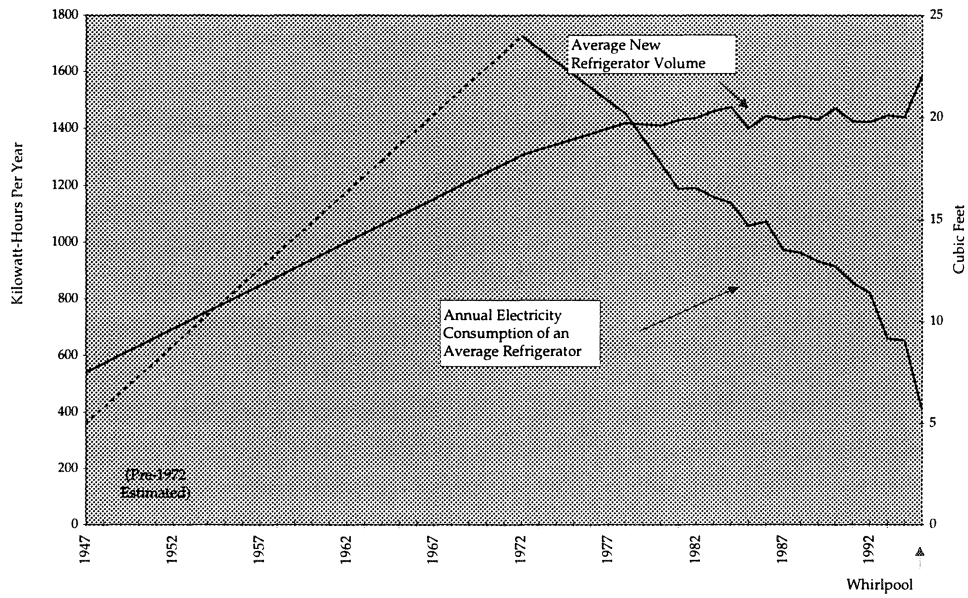
New Golden Carrot Whirlpool Design Reduces Consumer Costs......



megawatt-hours will be saved, cutting carbon dioxide emissions by approximately 85,719 metric tons.[236] Once the program's 250,000 refrigerators enter the market as planned, the program could result in direct annual energy savings of 96,000 megawatt-hours (a capacity equivalent of 16 megawatts) and 1.83 million life-cycle megawatt-hours—cutting carbon dioxide emissions by about 60,787 metric tons each year and by about 1,158,756 metric tons over the life cycle of the refrigerators.[237]

The indirect effects of the program, however, produced the greatest benefit. Because of the program, the entire market for refrigerators could be transformed; Whirlpool's competitors are also now developing more efficient refrigerators.[238] The Golden Carrot™ concept could be replicated to encourage improved efficiency designs for buildings, equipment, and appliances. Federal, state, and local governments could form partnerships with local utilities, manufacturers, and other interested parties to encourage improved efficiency through similar incentive schemes for technology demonstration and marketing.

Refrigerator Electricity Use and Volume *chart 10*



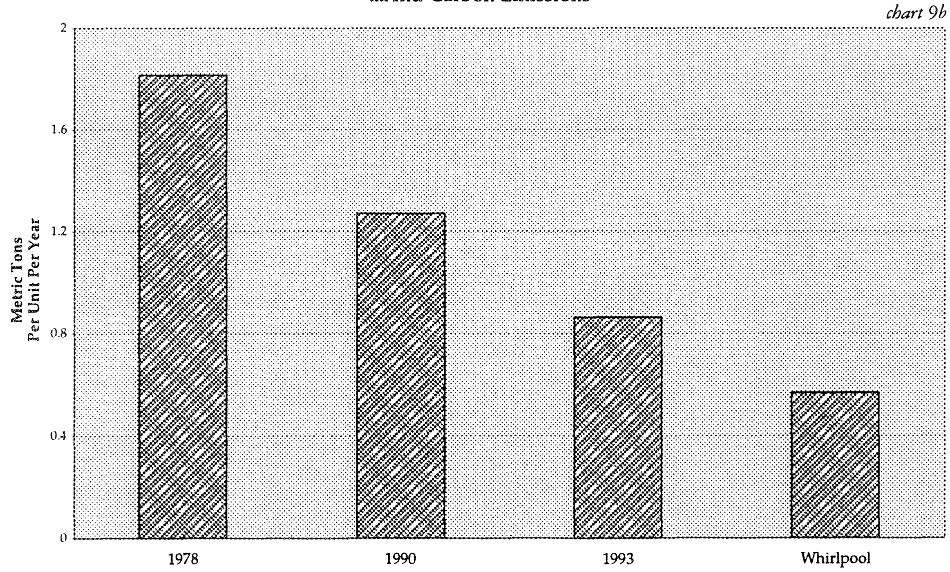
Source: Association of Home Appliance Manufacturers, Lawrence Berkeley Laboratory

2. Energy-Efficient Windows

Residential and commercial windows in the United States leak as much heat every year as is produced from the annual output of the Alaskan pipeline—approximately 1.8 billion barrels of oil per day costing $25 billion.[239]

• ***Lawrence Berkeley National Laboratory.*** The DOE's program at the LBNL has made an enormous contribution to national energy efficiency through its development of low emissivity, or "Low-E," windows, which use a special coating to reduce heat loss by 35 percent. LBNL helped private businesses develop prototype coatings and new, low-cost, thin-film deposition processes. Today, Low-E windows have captured 36 percent of the U.S. windows market with $600 million in annual sales. By 1993, the cumulative energy savings to the United States was $760 million, and cumulative savings will reach $17 billion by the year 2015. By that year, Low-E windows are projected to be preventing, through avoided electricity generation, 142,000 metric tons of sulfur dioxide, 129,000 metric tons of nitrous oxide, and more than 64 million metric tons of carbon dioxide emissions.[240]

...And Carbon Emissions *chart 9b*



Source: Super Efficient Refrigerator Program

3. ENERGY-EFFICIENT EQUIPMENT LABELING

• ***EPA's "Energy Star" Program.*** EPA's "Energy Star" equipment program affixes a readily-identifiable energy-efficiency label to office equipment that meets certain specifications for energy savings. The label is currently used by personal computer, monitor, printer, copier, and fax machine manufacturers whose products offer a low-power "sleep" mode when not in use (with no loss in performance) and can awaken automatically when needed.

Computer systems consume 5 percent of all commercial electricity—a percentage that could grow to 10 percent by the year 2000. Some 30 to 40 percent of all computers are left on at night and over weekends. On an average day, computers are active less than 20 percent of the time.[241] By using Energy Star equipment, an office with 100 PCs and monitors, 20 printers, and 10 fax machines could save about $3,800 per year.

D. Conclusion

Much more could be done to improve the energy efficiency of America's buildings, residences, appliances, and equipment. Fifty percent of large businesses that spend at least $100,000 annually on energy bills invest in energy efficiency only when paybacks are 2 years or less. This is equivalent to demanding better than 50 percent annual returns on financial investments. Energy-efficiency investments simply make good sense: they offer returns superior to those of most financial instruments, and they often improve worker comfort while significantly increasing productivity. Energy-efficient building designs, retrofit investments, and equipment and appliance standards all contribute to greater business competitiveness and economic growth—while preventing carbon dioxide emissions.

IV. Transportation

The combustion of fossil fuels by the U.S. transportation sector consumed 35 percent of the nation's energy in 1990 and produced more than 32 percent of U.S. carbon dioxide emissions.[242] Transportation will be the fastest-growing source of U.S. carbon dioxide emissions over the long term—by far—unless Americans take aggressive steps to build efficiency into transportation systems.[243]

Two-thirds of total U.S. oil consumption goes to transportation.[244] Transportation is the only sector of the U.S. economy that is totally dependent on oil. Oil consumption by transportation has profound implications for national security. Each day, Americans use 4 million more barrels of oil for transportation than the United States produces. The United States imports more than half the petroleum it uses, and those imports contributed $56 billion to the U.S. trade deficit in 1994.[245] The United States is importing more oil than ever before, and the trend is upward. The gap between what we use and what we produce is projected to rise to 9 million barrels per day by the year 2010.[246] Dependence on oil imports threatens U.S. national security.[247] It makes our economy vulnerable to foreign cartels, price swings, supply disruptions, and foreign wars.

Transportation energy use accounts for about half of all air pollution emissions in the United States and more than 80 percent of air pollution in cities.[248] Highway vehicles alone account for 26 percent of U.S. emissions of volatile organic compounds (VOCs), 32 percent of nitrogen oxides, and 62 percent of total carbon monoxide.[249] Emissions of these hydrocarbon vapor emissions are tied to gasoline use. Hydrocarbon by-products of gasoline consumption react with nitrogen oxides to form ground-level ozone, a major air pollutant that aggravates asthma and causes other respiratory problems. The American Lung Association (ALA) estimates that the United States spends $50 billion each year on health care as a direct result of air pollution.[250]

Every tank of gasoline consumed by an automobile produces between 240 and 400 pounds of carbon dioxide when burned.[251] Every pound emitted accumulates in the atmosphere for between 50 and 200 years.[252] The United States emits almost as much carbon dioxide from the transport sector as Eastern Europe, Southeast Asia, China, Africa, Latin America, and the Middle East combined.[253]

A. Fuel-Efficiency Improvements in Internal Combustion Engines Cost-Effectively Reduce Air Pollution, Including Carbon Dioxide Emissions

A huge potential exists for increased energy efficiency in transportation, which would benefit our national economy, national security, global industrial competitiveness, and the environment. Great strides have been made since 1970 in improving fuel efficiency and in reducing air pollutant emissions. Perhaps more than any other sector of the economy, however, transportation stands to gain the most from a concerted, national effort to mobilize efficiency improvements. Increasing transportation efficiency requires a duel strategy of building more-efficient vehicles while increasing the options for alternative modes of mobility—including transit, biking, and walking.

1. Internal Combustion Engine Efficiency Has Improved

Today's internal combustion engines are less than 25 percent efficient.[254] Only about 13 percent of the energy consumed by today's vehicles actually propels them forward.[255] Each year U.S. drivers spend $77 billion on gasoline and oil for their vehicles—with the bulk of each gallon of gasoline discharged through the tailpipe as waste exhaust.[256] Much of this energy need not be wasted.

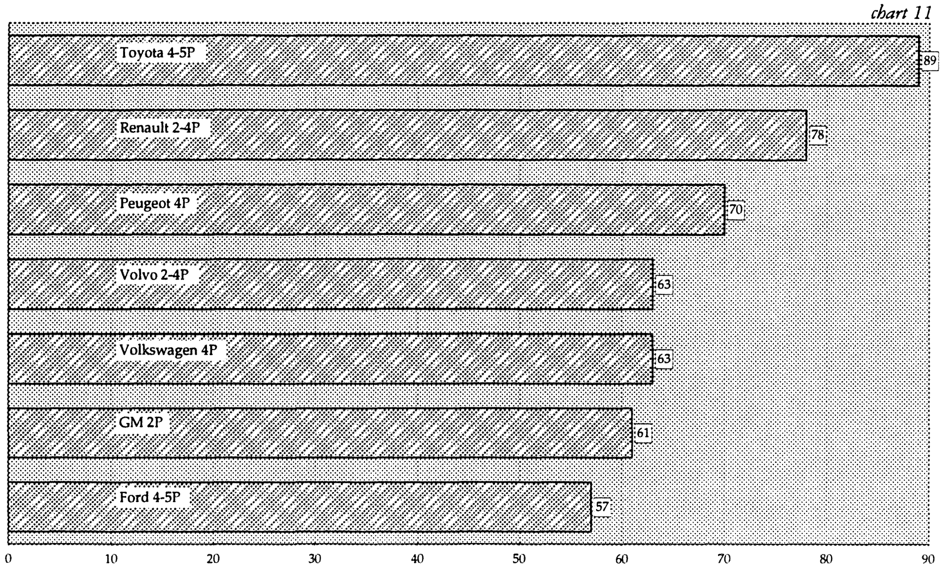
The increase in automobile fuel efficiency already achieved is an important transportation success. The technology exists, however, to substantially improve fuel efficiency in internal combustion engines. The most efficient cars now on the road achieve more than 45 miles per gallon (mpg). Commercial prototypes boast more than 70 mpg *in the city*.[257] Technology exists to raise average new-car fuel economy 65 percent, from 28 to 46 miles per gallon, by 2005. A comparable increase can be made for light trucks.[258] Phasing these improvements into U.S. cars and light trucks over the next 10 years could save 2.8 million barrels of oil per day by 2010. These savings are larger than the supplies expected from exploiting reserves offshore or in the Arctic National Wildlife Refuge.[259]

Because carbon dioxide emissions are proportional to fuel consumption, higher fuel economy means lower greenhouse gas emissions. If a 6 percent annual improvement trajectory in new vehicle fuel economy is started in 1996, annual greenhouse gas emissions could be reduced by 27 million metric tons in 2000 and by 152 million metric tons in 2010.[260]

These savings would be on top of substantial progress already obtained in

Efficient Prototype Vehicles

chart 11



Source: Union of Concerned Scientists

integrating energy efficiency into automobiles, including passenger cars and light trucks, over the past two decades. Automobiles required 40 percent less energy per vehicle-mile in 1990 than in 1970.[261] These efficiency gains are due in large part to technology-forcing regulations, especially federal Corporate Average Fuel Efficiency (CAFE) standards, as well as greater consumer acceptability and affordability of smaller vehicles. Between 1970 and 1990, the annual amount of fuel used per automobile declined by 25 percent.[262]

- ***Honda Motors Corporation.*** Honda has introduced a new high-efficiency Civic HX Coupe that meets the California low-emission vehicle (LEV) standard several years before the requirement goes into effect. The vehicle's continuously variable transmission (CVT) and lean-burn 1.6 liter engine give the vehicle up to 25 percent greater mileage over conventional automatics, at an economical price.[263]

2. Corporate Average Fuel Efficiency Standards Are a Significant Success

Federal CAFE fuel-efficiency requirements for new vehicles are one of the major energy policy success stories of the past 20 years. CAFE standards doubled automobile fuel efficiency from 14 mpg to 27 mpg between 1975 and 1985. The standards are presently saving nearly 3 million barrels of oil per day—corresponding to $50 billion of consumer savings and 150 million metric tons of greenhouse gas emissions avoided annually.[164]

Although average fuel economy for new cars has not improved since the mid-1980's, the technology has improved substantially during this time. Because CAFE standards failed to keep pace with engine-efficiency improvements, automobile manufacturers used the technological improvements to increase vehicle power rather than vehicle efficiency. With foresight and the right policies, improved engine technology is ready to increase fuel efficiency, thereby reducing carbon dioxide emissions and U.S. dependence on foreign oil.

3. Accelerated Vehicle Retirement Programs Can Improve Air Quality

As cars age, emissions can rise dramatically, sometimes increasing more than a hundredfold after only a few years. "Super-emitters" of air pollution are those 10 percent or so of cars and light trucks that account for half of all vehicle emissions. They also tend to reduce dramatically the average fuel efficiency of the U.S. fleet. Despite the federal 27.5 mpg CAFE standard, the fleet average is only 19.2 mpg, primarily due to continued use of older, less efficient vehicles.[265]

Accelerated vehicle retirement programs have been getting these older, more polluting vehicles off the road. In some jurisdictions, industrial sources are able to meet their Clean Air Act obligations more cheaply by buying and scrapping super-emitters than by installing pollution-control equipment.

- ***Chevron Corporation.*** In Southern California, Chevron Corporation is purchasing and dismantling 4,200 pre-1975 model-year cars under California's Rule 1610, which awards mobile source emissions credits to stationary source polluters that operate scrapping programs. Chevron plans to use the credits to forestall required installation of vapor-recovery technology at one of its off-shore oil terminals.[266]

- ***Total Petroleum Company.*** Total Petroleum Company in Denver, Colorado is scrapping 300 pre-1982 cars and repairing another 300 post-1982 models. The Denver Regional Air Quality District subjects each car to emissions testing prior to scrapping, and bases the number of pollution permits to be awarded to Total Petroleum on verified pollution reductions. The program targets cars that have been: (1) waived from the state's tailpipe inspection; (2) reported on a state "smoking vehicle hotline," where motorists are encouraged to inform the state of cars that exhibit signs of high emissions; and (3) deemed to be high emitters by remote sensing technology.[267] Total Petroleum is paying $1,000 for all scrapped cars and up to $500 for repairs to emissions-related parts.

4. Materials Improvements Are Cutting Vehicle Weight and Increasing Efficiency

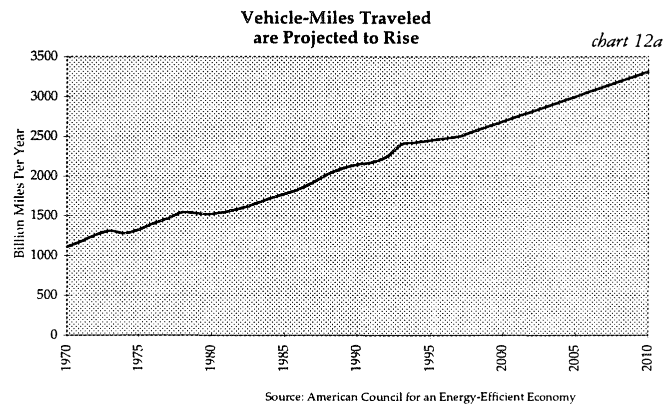
Many automakers have argued that raising mileage levels through more stringent CAFE standards means cutting car weight, size, and safety. But improvements in aluminum and plastic composites promise lighter, higher-mileage cars that will be just as big, safe, and powerful as today's models.

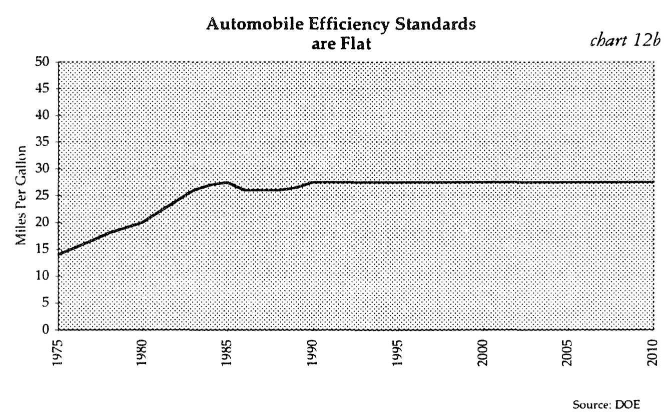
• ***Oak Ridge National Laboratory.*** The Oak Ridge National Laboratory in Oak Ridge, Tennessee coordinates a Lightweight Materials Program to develop cost-effective materials and technologies that will aid in automobile weight reduction while meeting or exceeding safety standards. The program also seeks to reduce the overall environmental impact of automobiles by minimizing process waste and increasing recyclability. A 25 percent weight reduction in current vehicles would save about 13 percent of total U.S. gasoline consumption, reducing carbon dioxide emissions by about 92 million metric tons per year.[268]

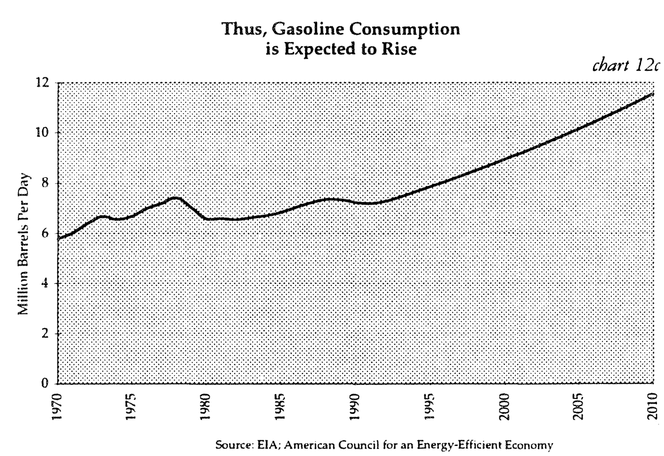
5. Vehicle Emissions Reduction Technologies Have Successfully Cut Emissions

New cars in the early 1990s emitted only about one-fourth as much pollution as uncontrolled vehicles of the 1960s.[269] This progress has been due primarily to federal uniform standards for new-car emissions.[270] These standards have spurred the development of numerous technologies, including cleaner fuels, advances in pollution-control technologies such as catalytic converters and electronic fuel-injection systems, better vehicle maintenance technologies, and inspection standards. Lead, for example, has been virtually eliminated from motor vehicle exhaust through the introduction of cleaner fuels.

Despite vast reductions in tailpipe emissions, automobiles are still a primary source of urban air pollution. This is because people are driving







more—racking up 43 percent more vehicles miles traveled (VMT) each year.[271] Increases in the number of vehicle miles traveled has more than offset increases in average vehicle fuel economy. Every American travels, on average, nearly 8,800 miles each year in a car or light truck, and the rate of increase in per capita VMT is growing at more than 2 percent per year.[272] In the absence of additional efficiency standards, total end-use carbon emissions in the transport sector are projected to increase by 90.7 million metric tons between 1990 and 2010, because growth in personal and freight travel is projected to outpace fuel-efficiency improvements.[273]

B. New Vehicle Technologies are Ushering In an Era of More Efficient Transportation

1. Technology Incentives Spur Markets For Efficient Vehicles

Faced with increasing vehicle emissions and the prospect of failing to attain federal Clean Air Act standards, several U.S. jurisdictions are implementing policies that require greater vehicle efficiency.

- ***The California Air Resources Board.*** The California Air Resources Board (CARB) has galvanized a low-emission vehicle (LEV) and zero-emission vehicle (ZEV) market in California by requiring automobile manufacturers to include at least 2 percent zero emission vehicles in their 1998 vehicle sales (an estimated 31,000 vehicles). Sales must rise to 5 percent by the year 2001 and 10 percent in 2003.[274] The level of overall ZEV investment, in both human and financial terms, has been remarkable, reaching as high as $500 million by some estimates. The California ZEV program has the capacity to create a trillion-dollar industry of environmentally clean transportation products that will create millions of jobs and investment opportunities in the United States and around the world. The California ZEV mandate has been embraced by Vermont, Massachusetts, and New York, and is being seriously considered by a number of other states.[275]

2. New Low-Emission and Zero-Emission Vehicles Could Revolutionize Transportation

More than a dozen companies are deploying LEV and ZEV vehicles, anticipating a potentially huge future market. The new designs may be three to five times as efficient as today's, and reduce emissions of regulated pollutants by at least 95 percent. Carbon dioxide emissions could decline by 75 to 90 percent.[276]

- ***Calstart, Inc.*** Calstart is a public-private consortium founded in 1992 to help California companies foster an advanced transportation industry by arranging for grants, marketing their products, and sharing information. It is a leading player in the state's efforts to support LEV and ZEV vehicles. More than 150 member companies have joined forces and are developing advanced transportation technologies. Thus far, member companies have deployed an aluminum chassis for electric vehicles, opened one of the largest production sites for natural gas vehicles, developed the first electric-natural gas hybrid vehicles, developed the first electric-natural gas hybrid bus, and introduced the nation's first electric school bus. Through June 1995, the member companies had created 1,655 jobs.[277]

- ***DOE's "Clean Cities" Program.*** The U.S. DOE "Clean Cities" program has successfully expanded the use of vehicles that use alternative fuels in 34 communities that have received a Clean Cities designation. Clean Cities communities intend to have more than 60,000 alternative fuel vehicles in use by the end of 1996, and will establish 700 refueling and maintenance facilities.[278]

a. Electric Vehicles

Electric vehicles are the closest thing to a nonpolluting transportation medium. Their only adverse effects on the environment would be linked to the generation of electricity to charge their batteries and, possibly, to disposal of the batteries (although recycling may dispel this concern).[279] Although the initial price of electric cars will likely be higher than the price of internal combustion engine vehicles, electric vehicles will have lower overall life-cycle costs.[280] Inadequate batteries, at present, are the only significant obstacle to widespread use.[281]

- ***South Coast Air Quality Management District (SCAQMD), California.*** In July 1995, SCAQMD unveiled a two-year "Electric Vehicle Incentive" program to help bring electric vehicles to the market. Beginning in 1996, SCAQMD will offer a $5,000 discount for motorists purchasing an electric vehicle, up to a total of 1,200 vehicles. The vehicles will be required to meet certain minimum performance specifications and all federal motor vehicle safety standards. In addition to this program, SCAQMD will use an additional $1 million to encourage the development of electric vehicle corridors. Under this program, groups of three or more clustered cities along designated corridors can apply for matching funds to help develop electric vehicle infrastructure.

• *General Motors Corporation.* Many manufacturers are moving ahead with electric vehicle production. General Motors originally unveiled its "Impact" model in 1990.[282] The Impact, with a composite body and stiff aluminum frame, incorporates an advanced electric motor, electronic controls, regenerative braking, and aerodynamic streamlining. The energy cost of running an Impact is only a quarter that of a gasoline-powered car. The driving range, however, is limited to about 100 miles by its 1,100 pounds of lead-acid batteries.[283] Nevertheless, those who have test-driven an Impact have on the whole given it rave reviews for its quiet ride, maneuverability, and rapid acceleration.[284] Even counting the emissions from the power plants used to charge it, the Impact produces two-thirds less pollution than California will allow under its 1998 ultra-low emission standard,[285] and 72 percent less carbon dioxide than is emitted by a 1994 Ford Taurus.[286]

• *Clean, Intelligent Transportation, Inc. (CITI).* Calstart and a Norwegian consortium joined forces recently and unveiled a personal electric car designed for affordability, with a sticker price of less than $10,000. The new company, Clean, Intelligent Transportation, Inc., will bring the new car, the PIVCO CITI, to California, and plans to begin manufacturing there by late 1996 or early 1997. The car is a roomy two-passenger vehicle that will be marketed as a commuter car for use as a family's second car to be used primarily for commuting and running errands around town. The car will run at freeway speeds, includes air conditioning, and will, with its dual air-bags, meet U.S. safety standards. The car will have a range of 60 to 80 miles between charges.[287]

• *Solectria Corporation.* Solectria, of Wilmington, Massachusetts, has produced a lightweight electric sedan with the standard features typical of sedans on the market today. With its aerodynamic styling, the new *Sunrise* sedan incorporates a state-of-the-art AC induction drive system and a driving range of 120 miles per charge, using advanced lead-acid batteries. (Enhanced range is expected as superior battery technologies are introduced in the future. A *Sunrise* prototype using a nickel metal-hydride battery has logged 238 miles in mixed city-highway driving without stopping for a charge.) The two-door, four-passenger electric vehicle includes power brakes, dual air bags, cruise control, automatic battery thermal management for winter driving, efficient electric air conditioning/heating, and a sophisticated onboard battery charging and monitoring system. The car accelerates from zero to 30 mph in 6 seconds, zero to 60 mph in 17 seconds, and maintains a cruising speed of 75 mph. The vehicle is projected to cost $20,000 at a mass-production level of 20,000 units, and will be available in 1998. Over the past 6 years, Solectria vehicles have consistently achieved top honors for efficiency, range and performance.[288]

b. Hybrid-Electric Vehicles

Hybrid-electric vehicles are another promising technology that could increase the efficiency of automobiles, retaining most of the environmental advantages of a battery-powered model without the huge quantity of batteries that weigh down pure electric vehicles. Hybrid-electrics have both a battery-powered electric motor and a small combustion engine, which are used either separately or together, depending on the driving situation. In some modes, the engine runs continuously, efficiently and relatively cleanly, charging the batteries and greatly extending the vehicle's range. This advantage has prompted renewed interest in hybrids, with most large automakers developing models to meet either the zero-emission vehicle or ultra-low emission vehicle standards that take effect in some regions in the next three to six years.[289]

• *Mitsubishi Motors.* Mitsubishi has come out with a prototype hybrid-electric vehicle that can attain top speeds of 95 miles per hour. Running on the battery alone, the vehicle achieves zero local emissions. When stored energy levels fall, a gasoline engine/generator takes over to provide wheel power while simultaneously recharging the battery. The vehicle's driving range is 150 miles on one tank of gasoline. Ford and GM are both working on advanced hybrid vehicles in programs cofunded by the U.S. DOE.[290]

c. Fuel Cells

Fuel cells could represent a whole new era in transportation technology, and a significant advance over both internal combustion and battery-powered vehicles. NASA employed fuel cells in the Apollo spacecrafts and space shuttles; using them to power automobiles, however, could become their most important application. Fuel cells transform hydrogen and oxygen into electricity. In an automobile, a fuel cell's power train would consist of a storage tank that holds hydrogen or a hydrogen-carrying fuel such as methanol, a fuel cell system that converts the fuel into electricity, and an electric motor. Given their greater efficiency and lower operating costs, fuel cell vehicles are likely to have lower life-cycle costs than gasoline or battery-powered vehicles.[291]

Fuel-cell vehicles would have many advantages, including zero emissions, quiet operation, long range, and unparalleled energy efficiency. Fuel cells run on methanol, natural gas, or petroleum—and would dramatically reduce pollution and cut greenhouse gas emissions and energy consumption by at least half.[292] The greatest promise involves powering future fuel cell vehicles with solar-derived hydrogen.[293]

- Three fuel cell buses have been built under the supervision of ***Georgetown University*** with funding from the U.S. DOE. All three are powered by methanol, a phosphoric-acid fuel cell made by Fuji Electric, and a nickel-cadmium battery available for peak-power needs, such as hard accelerations and climbing steep hills. Several smaller fuel cell vehicles are under construction as well. In late 1993, ***Energy Partners***, a start-up company in Florida, rolled out a fuel cell car running on compressed hydrogen. ***Daimler-Benz*** unveiled a van running on a fuel cell and hydrogen in April 1994. ***General Motors*** is building a methanol fuel cell car to be completed by 1996. In mid-1994, the U.S. DOE announced contract awards of $13.8 million to ***Ford*** and $15 million to ***Chrysler*** to develop fuel cells for light-duty vehicles. Both intend to use hydrogen as the on-board fuel.[294]

- ***The City of Palm Desert, California.*** Palm Desert is participating in a $4.23 million-dollar multi-organization project to build and test eight fuel cell-powered electric vehicles during the next three years. These vehicles will run on hydrogen that will be produced by a solar photovoltaic array near Palm Desert's City Hall and a wind turbine north of the city. Unlike battery-powered vehicles, which may be associated with some air pollution from the electricity generation plants, these vehicles will truly have zero emissions.[295]

C. Improving the Efficiency of Other Transportation Modes Reduces Carbon Dioxide Emissions While Improving Competitiveness

Energy efficiency has improved the way the United States transports commercial products, and the way public transit moves people. Efficiency reduces costs, thereby increasing competitiveness at the same time that it reduces carbon dioxide emissions.

1. Air Transport

In 1993, air transport accounted for 13.5 percent of total U.S. transportation energy use. This figure is expected to rise to 15.5 percent in 2010. Efficiency gains in air transport are a clear success. Over the past 20 years, air transport has achieved the largest improvements among all transport modes—halving energy use per passenger-mile. In the past, fuel costs exceeded 40 percent of an airline's direct operating costs. Those airlines that have adopted cost-effective efficiency technologies have managed to remain competitive while cutting fuel to 15 to 20 percent of operating costs. Despite these gains in fuel efficiency, the expected rise in passenger miles traveled means that U.S. air transport carbon dioxide emissions are expected to rise from about 475 million metric tons today to between 650 and 1,100 million metric tons in 2015.[296]

D. Long-Term Solutions Must Include Improved Urban Design

For the last 40 years, urban form has revolved around the automobile. Engineers have designed roadways to enhance vehicle speeds, rather than pedestrian safety. In many suburban developments, the sidewalk has disappeared altogether. Shopping centers are often set far from residential areas. Catering to patrons who arrive by automobile, they provided excessive parking, limited pedestrian assess, and no bicycle facilities.

America has become a nation where the automobile seems necessary to accomplish daily tasks and leisure pursuits. Road systems are often unable to keep up with demand and congestion continues to worsen. The spatial separation between jobs, homes, stores, and recreation is increasing. Those segments of our society that do not drive have been marginalized from mainstream society and employment opportunities.

If the United States is to seriously address carbon dioxide emissions in the transportation sector, it will be necessary to reorient our urban design toward people rather than cars. Urban structures cannot be changed overnight. However, there are signs that efforts to improve urban design have already begun. The goal is to create more livable communities. The side benefit will be cleaner air and reduced carbon dioxide emissions.

• ***St. Louis' MetroLink.*** One urban design success story is St. Louis' light-rail system, MetroLink. Using federal highway funds for construction, the system opened in 1993, 32 years after the city's last commuter rail line closed. Careful planning, implementation, and promotion have made MetroLink a model transit and land-use planning success.

MetroLink is an economic boon to the city, and people find they both like and *use* the rail line. It has reduced traffic on St. Louis' most congested freeways and lowered demand for downtown parking facilities. MetroLink uses less energy per mile and produces less air pollution per passenger-mile than automobiles. The system reached its five-year ridership goal in its first year. The citizens of St. Louis approved a sales tax increase to expand MetroLink and improve other transit services.

The most significant factor in MetroLink's success is its land-use planning approach: St. Louis uses a radial corridor land-use pattern. Radial patterns lend themselves to transit development because population densities in the corridors tend to be high, increasing chances that ridership, too, will be higher than it would be in cities with grid development patterns. Also, radial corridor cities tend to have a lot of magnets—shopping centers, museums, and sports arenas—within walking distance of transit stations. MetroLink facilitates a resurgence of a land-use pattern more widely known before the age of the automobile—the American village land-use pattern—where most daily conveniences were located within walking distance. This pattern could prevail for land-use planning in the 21st century.[297]

• ***Chicago's Community Green Line Initiative.*** The Community Green Line Initiative is a planned community-based transit-oriented development centered around the Pulaski Street Station in Chicago. The Pulaski Street Station is part of what used to be the Lake Street Elevated Line—now the Green Line—one of Chicago's historic elevated transit lines. In 1994, the line shut down for a two-year reconstruction project, which will include building or renovating 28 transit stations.

Within a half mile of the Green Line live 118,000 people—a population similar to a small city. Only half of these households have access to a car. Members of the community developed the Green Line Initiative to boost transit ridership, reduce automobile dependence, stem the abandonment of buildings, and increase job opportunities—all while contributing to regional air quality goals. West Garfield, the community surrounding Pulaski Station, has suffered greatly from development patterns that favor sprawl, structural disinvestment, and suburban infrastructure funding—all patterns that continue to contribute to the social and economic disintegration of inner cities across the United States. The Community Green Line Initiative has encouraged citizen involvement in planning, and seeks to upgrade the neighborhoods surrounding the Green Line by making the area an attractive place to live, work, raise families, and shop. New jobs will be created—within walking distance of workers' homes. The land-use plan calls for rebuilding neighborhood density with new housing, revitalizing the neighborhood economy with retail and commercial development, and creating new public parks.

The Green Line Initiative has taken advantage of federal funds made available through the Intermodal Surface Transportation Efficiency Act (ISTEA), which mandates broad changes in the way transportation decisions are made and funded, and the Congestion Mitigation and Air Quality Program (CMAQ), a component of ISTEA, which provides funds for projects that reduce traffic congestion and improve air quality. To help the initiative qualify for these funds, the American Lung Association (ALA) projected the air quality impacts of the project. According to the ALA, the Green Line Initiative will eliminate 17.5 percent of vehicle trips to work and 20 percent of all other trips, thereby saving 1,556 vehicle miles traveled every day. These reductions could cut ozone precursors, including VOCs, by 6.9 metric tons, and nitrogen oxides by 2.75 metric tons per year.[298]

E. Conclusion

Transportation will be the fastest-growing source of U.S. carbon dioxide emissions over the long term—by far—unless Americans take aggressive steps to build efficiency into transportation systems. Transportation is the only sector of the U.S. economy that is virtually totally dependent on oil. America is importing more oil than ever before, and the trend is upward. Transportation accounts for about half of all air pollution emissions in the United States, and more than 80 percent of air pollution in cities. Every tank of gasoline consumed by an automobile produces up to 400 pounds of carbon dioxide emissions.

Solutions to these transportation problems are within reach; what is needed is the political will to tackle them. Internal combustion engines are becoming increasingly efficient. Federal CAFE standards have doubled automobile fuel efficiency, saving nearly 3 million barrels of oil every day. Programs are helping retire older, more polluting vehicles from the road, while emissions-reduction technologies in new vehicles are being improved.

A revolution is underway in the transportation sector—the development of new low-emission and zero-emission vehicle technologies. The California Air Resources Board has implemented LEV and ZEV vehicle standards, which will take effect in 1998, that should spur a potential trillion-dollar market for environmentally clean automobiles. Several electric vehicle and hybrid-electric vehicle manufacturers are gearing up for mass production.

If the United States is going to seriously reduce carbon dioxide emissions in the transportation sector, however, long term solutions must include a reassessment of land-use planning. Communities nationwide are seeking to redesign urban structures around people, rather than around traffic. Several new urban designs maximize the benefits of locating conveniences within walking or bicycling distance.

IV. RENEWABLES: COMING OF AGE

Renewable energy technologies—wind, photovoltaics, solar-thermal, and geothermal[299]—have made major advances in the past decade, and are rapidly becoming a means of minimizing the costs of providing energy services. Renewables can assist utilities with environmental regulatory compliance, protect ratepayers from fluctuations in fossil-fuel prices, diversify the energy supply mix, improve air quality, cut public health costs, and improve local economies as a result of market demands for, and export of, cleaner technologies.[300]

Renewable energy costs have dropped while reliability and performance have improved dramatically. For example, the cost of wind-generated electricity in the United States dropped from 25 cents per kilowatt-hour in 1984 to less than 5 cents per kilowatt-hour today.[301] The cost curves for solar-thermal and photovoltaic utility plants show similar downward trends. Increased production would further reduce costs.[302] If pollution and social costs from fossil use were to be internalized in fossil prices, many renewables today would be cheaper than fossil fuels. With support from forward-looking public policies, renewables could play a strong role in meeting future U.S. energy needs.

A. Renewables Technologies Have Made Major Advances

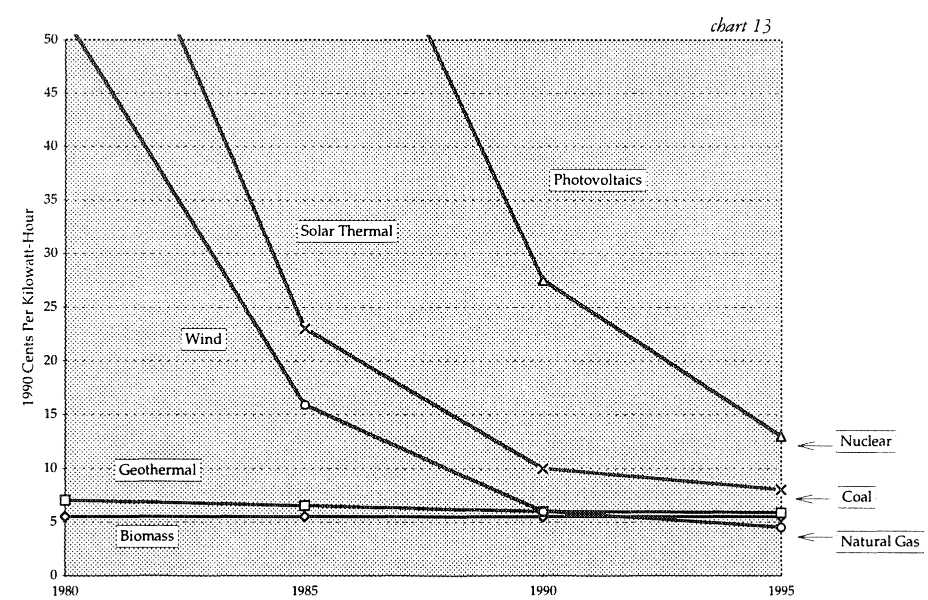
When Congress enacted the 1978 Public Utility Regulatory Policies Act (PURPA),[303] it required utilities to buy renewables-generated power at the utility's "avoided costs"[304]—which sparked the first major deployment of renewable energy in the U.S. market. Since then, approximately 12,000 megawatts of nonhydroelectric renewables have come on line. Several states, particularly California, have encouraged the development and deployment of renewable resources, and have experimented with a variety of mechanisms to push renewables into the marketplace.

The costs of renewables have dropped, allowing them to compete with more conventional power generation. The U.S. DOE projects a continued drop in prices. At the same time, renewable capacity is expected to grow. By 2005, renewable capacity in the United States could increase to 4,180 megawatts of wind, 260 megawatts of photovoltaics, 3,440 megawatts of geothermal, and 12,500 megawatts of biomass and municipal solid waste energy.[305] U.S. export opportunities for renewables and efficiency technologies have become one of the fastest-growing economic sectors.[306]

B. Renewable Energy Has Become Reliable

The reliability of renewables has improved markedly. Although renewables by their nature provide power intermittently (when the sun shines or the wind blows), technological improvements have made renewable energy highly reliable. For example, new models of wind turbines are up and running 95 percent of the time the wind blows. Many renewable technologies can generate electricity as part of base load or are otherwise dispatchable; geothermal units can have capacity factors greater than 90 percent.[307] For comparison, the average capacity factor for all operating coal-fired power plants in the United States was 60 percent from 1990 to 1994. A recent National Renewable Energy Laboratory study suggests that intermittent generation load levels of at least 10 percent (and perhaps as high as 20 percent) can be accommodated with no adverse system impacts.[308] In California, Pacific Gas and Electric uses wind to supply as much as 7 percent of its system load—5 percent during peak hours—with no adverse effects.

Renewable Energy Costs are Dropping



Source: DOE, Energy Foundation

• *EnergyWorks.* Bechtel recently joined forces with PacifiCorp of Portland, Oregon to form EnergyWorks, a joint venture based in Landover, Maryland to develop, finance, own, and operate small, renewable energy systems, including solar, wind, and hybrid energy systems. Bechtel's president, John D. Carter, sees the venture as an opportunity in an increasing global shift toward renewables. EnergyWorks' president and CEO Jeffrey W. Eckel notes, "The use of new renewable energy technologies is growing at a rate between 10 and 20 percent annually in a number of markets," including foreign markets. The EnergyWorks venture reflects the growing economic viability of renewable energy.

C. The Growth of Renewables Depends on Several Factors

Several factors affect renewable electricity development, including:

• ***Prices of competing fuels, especially natural gas.*** The current and forecasted price of natural gas and other fossil fuels will continue to influence the business climate for renewables, affecting utility power purchases, the competitiveness of renewables in bidding solicitations, and the availability of private investment capital and government support. Deploying renewables has high up-front capital costs, but typically extremely low operating costs because there are no fuel costs. On a life-cycle basis, renewables often have lower costs.[309] Nevertheless, at present, natural gas beats renewables on a first-cost, short-term basis. Modular natural gas facilities currently produce electricity at around 3 cents per kilowatt-hour, or less. Although fossil prices, including natural gas prices, will inevitably rise, it is uncertain when.[310]

• ***Evolving electric power regulation.*** Because renewables have difficulty competing with natural gas on a first-cost basis, regulatory treatment is critical to the future development of renewable electricity. Legislative incentives and regulatory policies favoring renewables have been responsible for the bulk of purchase contracts awarded to renewable electricity developers to date. Just ten states have accounted for more than 70 percent of U.S. renewables development (excluding hydropower development by utilities), which shows the importance of state utility regulatory policy.[311]

• ***Environmental externalities.*** A key question in the utility industry restructuring debate is whether, or how, the price of fossil fuels will be adjusted to account for the environmental and social costs associated with their extraction and combustion. At present, these externalities are not fully incorporated into market prices. Since renewable electricity technologies consume less water and generate much less air pollution, hazardous waste, and carbon dioxide emissions, they would see wider use in markets that internalize the environmental costs of energy production. According to the National Renewable Energy Laboratory, as of early 1994, 29 states and the District of Columbia required electric utilities to consider environmental externalities in their resource planning processes. Seven of these states—California, Massachusetts, Minnesota, Nevada, New York, Oregon and Wisconsin—have developed monetary values for pollutant emissions. The momentum toward quantifying and incorporating the costs of environmental externalities, however, has recently stalled.[312]

• ***Future Cost Curves of Renewables.*** Further cost reductions could greatly enhance the market penetration of renewables. Reductions in the price of renewables are dependent, however, on the willingness and the ability of private industry, the federal government, and electric utilities to continue to fund technological research, demonstration, and commercialization programs. Regulatory uncertainty and overcapacity in the market have slowed needed investments in renewables, while Congress is scrutinizing the U.S. DOE's budget and is even considering abolishing the department altogether.[313]

• ***Foreign Competition.*** Although the United States has pioneered most renewable electricity technologies, the foreign rate of development for these technologies is beginning to surpass the U.S. pace.[314] If the U.S. market continues to be inhospitable, it may force renewables development overseas. If the United States fails to develop aggressively its own renewables market through public incentives, the future U.S. energy infrastructure could become dominated by foreign firms.

D. Four Promising Renewables Industries

Despite current impediments, continued technological development and inevitable increases in fossil energy prices could make renewable sources the fastest growing—and perhaps the dominant—source of power in the 21st century. Reviewed below are four renewable industries—wind, photovoltaics, solar thermal, and geothermal—for which the near-term viability of commercial deployment vary widely.

1. Wind Power

The advancement of wind energy is a convincing success story. The wind industry is producing utility-scale turbines that are significantly less costly and far more reliable than earlier generation turbines. Newer turbines are routinely available for generation more than 95 percent of the time, and utility contracts for wind power have been signed recently for a levelized price of less than 4 cents per kilowatt-hour—a price that is competitive with fossil sources and cheaper than nuclear.[315] Wind has enormous advantages over fossil fuels, including minimal future costs subject to inflation[316] and low operating and maintenance costs.[317] Wind energy is one of the least costly sources of new electrical generation and is competitive with new fossil fuel-fired plants.[318]

Wind power has another advantage—its modularity. Wind turbines individually cost a fraction of what a conventional power plant costs, and a generator can install as many wind turbines as it needs, when it needs them, and with lead times of about one year.[319]

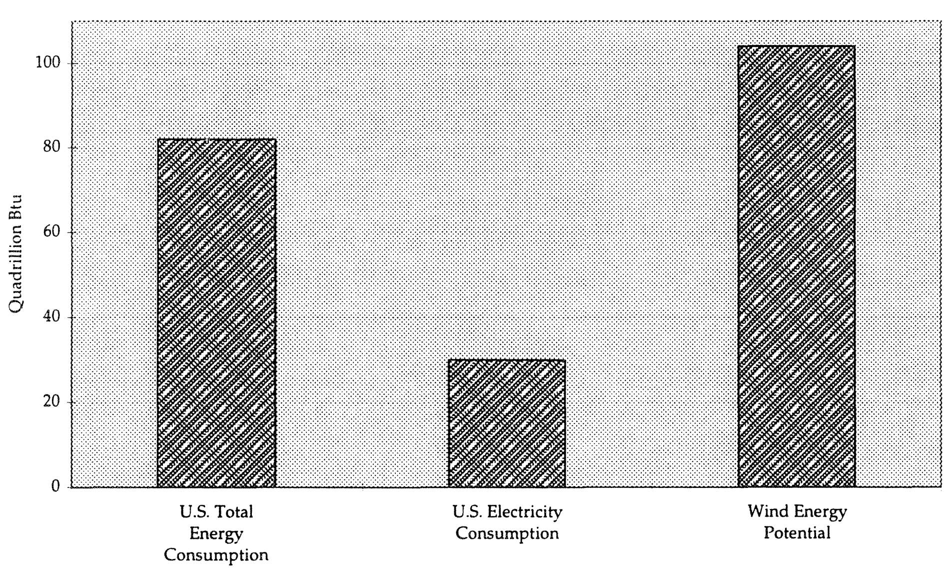
The cost of wind energy ranks well below all other energy sources when measuring rational, economic costs.[320]

In spite of wind energy's declining costs, the market still presents numerous barriers. As utilities turn to market mechanisms, such as bidding, to determine the type of power plants that will be built, wind energy's beneficial attributes are being ignored in the "dash to natural gas"—the mid-1990s fuel of choice.[321] The market should discount future cost projections of fossil fuel-fired technologies because of price volatility.[322]

At the end of 1994, 1,717 megawatts of wind capacity had been installed in the United States, producing around 3.5 million megawatt-hours per year. (Using wind to provide 3.5 million megawatt-hours of U.S. generation avoids about 2.2 million metric tons of carbon dioxide emissions annually.[323]) The bulk of this capacity was installed in the mid-to-late 1980s. Far greater growth of wind installations has occurred in foreign markets. Europe accounted for 80 percent of the wind industry's sales in 1993, and Germany alone accounted for nearly half of worldwide wind capacity installed in 1994. Worldwide grid-connected wind energy capacity was 3,657 megawatts at the end of 1994, and generated more than 6 million megawatt-hours of electricity.[324]

The U.S. wind resource is large enough to supply more than 4.4 billion megawatt-hours—more than 1.5 times the total amount of electricity used in the United States.[325] A 1990 Battelle Pacific Northwest Laboratory study concluded that available wind technology under tight land use restrictions could economically produce 20 percent of the electrical needs of the contiguous United States on just 0.6 percent of the land.[326] Although wind power (without storage) is an intermittent resource, meteorologists have become reasonably accurate in predicting the energy profile of a wind resource in sites with good wind data.[327]

U.S. Wind Energy Potential *chart 14*



Source: Battelle Pacific Northwest Laboratory

• ***Kenetech Corporation.*** Kenetech Corporation, based in San Francisco, was formed in 1986 as the holding company for U.S. Windpower, Inc.[328] Kenetech, with more than 800 employees, is the world's largest wind company. It manufacturers and sells one of the most advanced wind turbines in the world, the variable speed Model 33M-VS. This turbine delivers electricity at less than 5 cents per kilowatt-hour, making it economically competitive with traditional fossil-fuel energy sources. Variable-speed turbines capture a higher percentage of available energy than did earlier designs, and rotate faster as wind speeds pick up to maintain steady power output to the utility grid. Kenetech is the only U.S. wind turbine manufacturer that is producing utility-scale turbines on a volume basis. Kenetech operates an installed base of around 4,400 wind turbines, most of which are in the United States.

An example of one ongoing Kenetech project is the Sacramento Municipal Utility District (SMUD) five-megawatt wind project, which began operation in 1994 using Kenetech turbines. The project produced energy at 4.3 cents per kilowatt-hour in its first year (non-inclusive of federal energy production incentive payments).[329] Kenetech provided SMUD with guarantees that its turbines would operate at 28 percent of capacity over two years and that the project will annually produce 121.7 gigawatt-hours—which offsets 41,743 metric tons of carbon dioxide from California's average annual generation.[330] SMUD has an option to expand the plant size to 100 megawatts.[331]

Overall in California, Kenetech generated 659,131 megawatt-hours of electricity in 1993, offsetting 226,082 metric tons of carbon dioxide emissions that would otherwise have been generated by California's average mix.[332]

• ***FloWind Corporation.*** FloWind, based in San Rafael, California, develops wind plants and manufactures and designs wind turbines. The company operates two wind farms with more than 860 turbines in the Altamont and Tehachapi Passes in California. FloWind pioneered commercial development of a vertical axis wind turbine (VAWT), and also has exclusive marketing rights to a 275-kilowatt horizontal axis turbine designed by Robert Lynette and Advanced Wind Turbine—the AWT-26.

During 1993, the company invested substantially in research and development for a new generation VAWT—a 17-meter "extended height to diameter" VAWT. FloWind began testing prototypes of this 300-kilowatt turbine in Tehachapi in early 1994 and plans to upgrade substantial portions of its two wind plants with the new turbine design. FloWind's VAWT design was developed in part with Sandia National Laboratories. Using a $3.2 million cost-shared research agreement with the DOE, FloWind conducted a study of possible advancements in the VAWT technology, and integrated a number of improvements that capture more wind energy and bring down costs.[333] Commercial production of the turbine is slated for 1995.

FloWind has grown into a company with 100 employees and annual wind turbine sales of $66 million, including $47 million in sales to India.[334] The total installed capacity of the more than 860 turbines operated by FloWind is around 140 megawatts, including 94 megawatts from turbines it owns. In 1993, FloWind generated 170,499 megawatt-hours of electricity in California,[335] offsetting 58,481 metric tons of carbon dioxide emissions that otherwise would have been emitted by California's average generation mix.[336]

• ***Zond Systems, Inc.*** Zond Systems, with headquarters in Tehachapi, California, is the second-largest producer of wind-generated electricity in the world. Zond's five operating wind facilities in California have a total generating capacity of about 260 megawatts. The company also has designed the largest U.S.-made turbine, rated at 500 kilowatts. The 500 kilowatt turbine—the Z-40— is a three-bladed, upwind, 40-meter rotor diameter machine developed with assistance from the National Renewable Energy Laboratory. Zond installed one Z-40 in Tehachapi Pass, California, in 1994.

In February 1994, the DOE agreed to provide Zond with a $1 million grant under the government's Value Engineered Turbine Program. Zond will use the funds to produce a prototype Z-40, test it in the field and release it for commercial production. Zond says it plans to begin building its first wind-power plant with Z-40 turbines in 1995.[337]

Zond generated 578,172 megawatt-hours of electricity in California in 1993,[338] which offset 198,313 metric tons of carbon dioxide that otherwise would have been emitted by California's average generation mix.[339]

2. PHOTOVOLTAICS

Photovoltaic (PV) power uses semiconductor technology to convert sunlight directly into electricity without the need for turbines, generators or any other moving parts. Photovoltaics' rapid evolution has been tied to advancements in solid state physics and, like the computer industry, its future development could revolutionize the way we live.[340]

Photovoltaics' inherently modular technology lends itself to a wide variety of applications, ranging from hand-held calculators to rooftop generating systems and central station power plants. Because of this flexibility, and because PV systems can be used in diffuse or direct light in all climates—including every state in the U.S.—PV technology appears to have the greatest potential of all renewable resources.[341]

PV production costs have fallen more than fiftyfold over the last 20 years, and generate power today at an average cost of 25 to 50 cents per kilowatt-hour for grid-connected applications. Grid-connected PV systems cost about $5 to $7 per watt to manufacture. At these prices, cost-effective PV applications are mainly for off-the-grid uses in remote locations where power is needed for water pumping, refrigeration, lighting, and communications. However, PVs can be cost-effective in specialized grid situations. For example, PV arrays sited at generating substations to support a utility's transmission and distribution system, and PV arrays sited at residential and commercial centers, have the potential to manage demand for electricity by shaving utility peak loads.

The ***Boston Edison Company*** has found cost-effective applications for PVs, even at today's prices. The Union of Concerned Scientists, in an extensive study, concluded that as much as 31 percent of Boston Edison's electricity could be supplied by renewables, including PVs. Boston Edison's break-even cost of supplying electricity (without adding in externalities) is $5.20 per watt—within the current cost range of PVs. PV technology has matured to the point where it can be cost-effective when transmission expansion is necessary, and can play an important role in utility transmission and distribution planning.[342]

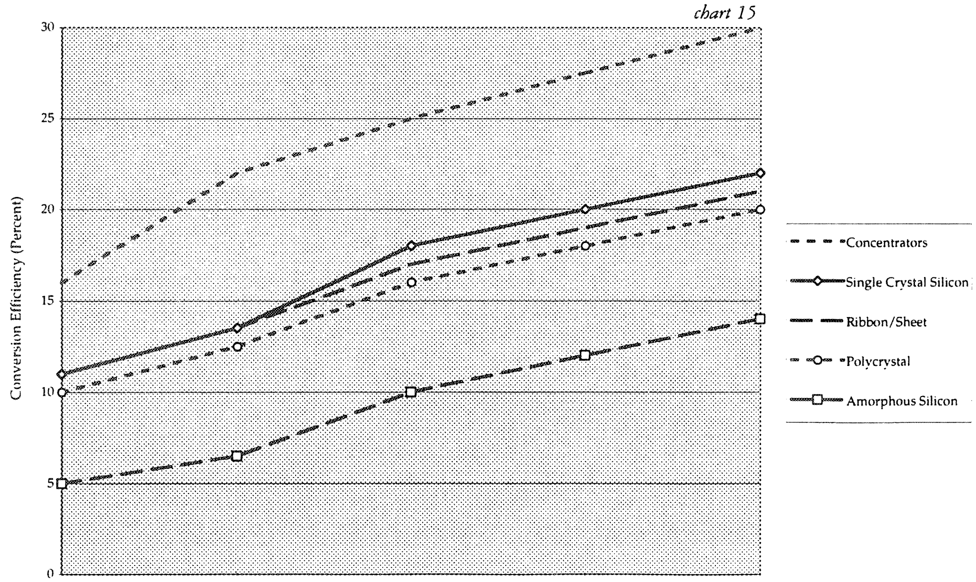
As of 1994, the U.S. had just 18 megawatts of grid-connected PV installed capacity, and 25 megawatts of additional PV in stand-alone applications.[343] These numbers are expected to climb. Chart 15 shows the five principal PV technologies currently under development, and their present and projected efficiencies. With prices dropping, PV generation is likely to become a major source of clean power by the turn of the century.

- ***Amoco/Enron Solar.*** The domestic PV industry received a boost in January 1995 when Amoco Corp., which owns Solarex—the largest U.S. manufacturer and marketer of PV systems—launched a joint venture with Enron Corp., the nation's largest natural gas company. Together, they propose to build a $25 million manufacturing facility to produce PV modules and a $150 million, 100-megawatt PV generating plant in Nevada that they maintain will be able to sell power profitably for 5.5 cents per kilowatt-hour (escalating by 3 percent annually over 30 years).[344] When production begins in 1996, the plant will manufacture in excess of 10 megawatts of large-area multijunction amorphous silicon modules annually.

- ***The Sacramento Municipal Utility District.*** The Sacramento Municipal Utility District (SMUD) is perhaps the utility most committed to solar energy in the country. SMUD has implemented a wide range of solar technologies, including 2 megawatts of PV arrays located at its retired Rancho Seco nuclear power plant, 600 kilowatts of PV arrays at its Hedge substation (where it has developed a highly cost-effective single-axis mounting strategy), PV electric vehicle recharging stations, and rooftop solar collectors for residential and commercial customers.

Photovoltaic Conversion Efficiency

chart 15



SMUD's "PV Pioneers" program has installed 4-kilowatt PV panels, manufactured by Siemens Solar, on customers' roofs, at a cost of $7.07 per peak watt. These customers seem eager to pay a premium for the satisfaction of generating and consuming clean, renewable electricity.[345] SMUD has installed more than 240 systems in Sacramento's residential neighborhoods, allowing the utility to gain valuable insights into decentralized generation, whereby customers also become generators, feeding small increments of power into the fingers of the distribution network where it is often needed most.

SMUD's PV programs produced 63,971 megawatt-hours of cumulative power between 1986 and 1994. This electricity output, had it been produced by California's average mix, would have pumped 21,942 metric tons of carbon dioxide into the atmosphere.[346] Instead, it was emissions-free.

- ***Siemens Solar Industries.*** The leading U.S. PV producer, Siemens Solar, based in Camarillo, California, shipped approximately 15 megawatts of PV modules in 1994, and 12.5 megawatts of PV modules in 1993, representing more than half of all U.S. PV shipments and 21 percent of the global market. In February 1995, the company announced its intent to increase production capacity by nearly 50 percent. Its core technology is single crystalline solar cells, but Siemens Solar also is developing copper indium diselenide thin-film cells.

Siemens Solar has also installed several grid-support systems. One is a 500-kilowatt PV installation at Pacific Gas and Electric Company's Kerman, California substation, which places the power generation source closer to the point of demand, reducing transmission and distribution costs. A second system, for the Sacramento Municipal Utility District, includes four-kilowatt residential rooftop systems and a 200-kilowatt single axis tracking PV system for transmission and distribution support. Siemens Solar is also providing Southern California Edison Co. with off-grid systems.[347]

3. Solar Thermal

Solar thermal systems convert energy from sunlight into thermal energy, which can either be used directly as heat energy or converted into electricity. Three solar thermal electric technologies—parabolic troughs, central receivers and parabolic dishes—are being developed in the United States today. All three technologies use tracking mirrors to reflect and concentrate sunlight onto a central receiver, where the conversion to high temperature thermal energy takes place.

a. Parabolic Troughs

Of the three technologies, only parabolic troughs have been developed to commercial scale.[348] Luz International, Ltd. installed parabolic trough technology at nine plants between 1984 and 1990. To finance the plants, Luz used federal and California tax incentives, international tax incentives for equipment purchases, and favorable power purchase agreements. Although Luz is now out of business, other owners are still operating its solar thermal plants, selling power to Southern California Edison. While Luz was operating the plants, it dramatically reduced generation costs from nearly 25 cents per kilowatt-hour in 1984 to around 9 cents per kilowatt-hour in 1989. Sandia National Laboratories estimates that new parabolic trough plants could produce electricity for 8 to 14 cents per kilowatt-hour, depending on tax incentives and plant size.[349]

b. Central Receivers

The second solar thermal technology, central receivers—or "power towers"—have yet to be demonstrated on a commercial scale.[350] However, a 10-megawatt plant is scheduled to begin operation in early 1996 and continue through 1998. The project, known as Solar Two, is a partnership between the U.S. DOE and a consortium led by Southern California Edison. The project is upgrading a prior 10-megawatt demonstration system, known as Solar One, that produced more than 35,000 megawatt-hours of electricity at an installed capacity cost of approximately $14,000 per kilowatt-hour.[351] The new system is expected to do better, and will use a molten salt thermal storage system, enabling it to assist Southern California Edison's peak demand period by extending electricity generation into the early evening hours.

- ***Bechtel Corporation.*** Bechtel, with headquarters in San Francisco, is the project team manager for Solar Two, the 10-megawatt central receiver "power tower" project sponsored by a consortium of 15 companies and utilities, as well as the U.S. DOE. The consortium and the DOE will split the total cost of the project, estimated to be $48.5 million. Bechtel designed the Solar Two system, which basically converts the Solar One facility in Daggett, California from a pressurized water/steam receiver and oil/rock storage system to a molten nitrate salt receiver and thermal storage system. Solar Two will be able to collect and store solar heat in molten salt during the day and then generate electricity with it during cloudy periods or in the early evening, during peak demand. Construction began on Solar Two in November 1994. The consortium hopes to bring Solar Two on-line in late 1995 and to complete testing in 1998. The sponsors of Solar Two also contracted with Bechtel to develop a plan to commercialize the technology.[352]

c. Parabolic Dishes

The third solar thermal technology, parabolic-dish generating systems, achieve the highest performance of the three solar thermal designs in terms of annually collected energy and absorption of peak sunlight.[353] During the past 15 years, about eight systems ranging in size from a few kilowatts to 50 kilowatts have been built and operated in the United States, although recent development has largely been confined to industry and government cost-shared research and development. The DOE is investing in a utility-scale joint venture to develop a 25-kilowatt system that utilizes advanced Stirling engines at the concentrator focal point. The DOE hopes to spark commercialization of dish/Stirling systems, and expects the systems eventually to achieve capital costs of $1,500 per kilowatt-hour (for systems augmented by fossil fuels) and a levelized energy cost of 6 cents per kilowatt-hour.[354]

• ***Cummins Power Generation, Inc.*** Cummins Power Generation (CPG) is a subsidiary of Cummins Engine Co. of Columbus, Indiana. CPG is America's foremost producer of dish/Stirling systems. CPG is developing two systems—a 7-kilowatt and a 25-kilowatt system— both of which were selected by the U.S. DOE's Joint Venture Program for commercial demonstration. Under both contracts, CPG's systems will employ a free-piston Stirling engine driven directly by high heater head temperatures of 675° Celsius. The entire structure of parabolic dishes will track the sun as it moves.

4. Geothermal

Geothermal energy is heat stored beneath the earth's surface. The amount of heat ultimately recoverable is dependent on the technology available to tap it. Some geothermal sites may be developed in a sustainable manner so that the heat withdrawn equals the heat being replaced naturally. Practically speaking, potential geothermal resources are so large that they are not considered depletable.[355]

Geothermal power has been in commercial production since about 1960, with the United States leading the world with more than 3,000 megawatts of installed capacity.[356] Since the early 1990s, however, geothermal development has been hindered by slumping U.S. energy markets in the West, where most of today's usable domestic geothermal resources are located. Despite a drop in geothermal electricity costs to between 4.5 and 7 cents per kilowatt-hour, low natural gas prices have made it difficult for geothermal to compete.[357] Nevertheless, because gas prices eventually will rise, geothermal resources have a tremendous potential to provide clean and sustainable energy in the future.

• ***Pacific Gas and Electric Company.*** Electric utilities, primarily Pacific Gas and Electric (PG&E), were the first in the United States to build geothermal generating facilities. PG&E owns about three-quarters of the capacity of The Geysers, a 35-square-mile dry steam field in Northern California, that has an infrastructure investment of about $3.5 billion. The Geysers has about 500 wells, most of which are 6,000 to 10,000 feet deep, tapping into a steam reservoir whose temperatures exceed 220° Celsius. The field has been in production since 1960, but began to decline in 1988, when it reached a peak output of 2,000 megawatts.[358]

PG&E has found geothermal to be highly economical. The first ten PG&E power plants at The Geysers—completed between 1960 and 1974—were all built for less than $200 per kilowatt. In the late 1970s, however, the cost of new plants at The Geysers started to rise because less desirable sites were used. Two PG&E units brought on-line in 1985 had an average capital cost of about $1,400 per kilowatt. More recent projects had an average capital cost of about $2,500 per kilowatt.

Despite the production decline at The Geysers, geothermal remains one of PG&E's lowest-cost sources of power over the life of the facilities, and in 1994 represented around 10 percent of PG&E's thermal generating capacity.[359]

• ***California Energy Company, Inc.*** California Energy Company, based in Omaha, Nebraska, is the world's largest independent geothermal power company, with operations in the United States, the Philippines, and Indonesia. The company operates 13 geothermal facilities with a total capacity of 575 megawatts, has contracted to provide over 1,500 megawatts in the future, and has projects under construction totaling another 540 megawatts.[360]

In 1990, the California Energy Company received the National Environmental Achievement Award for its 288-megawatt Coso project at the U.S. Naval Weapons Center in Inyo County, California. The company plans to expand this facility—a nine-unit steam geothermal complex—to around 600 megawatts.

In 1995, California Energy acquired ***Magma Power Co.,*** another leader in the geothermal industry, and made it a wholly-owned subsidiary. Magma Power operates seven power plants (three purchased from Unocal in 1993) totaling 264 megawatts in the Salton Sea Known Geothermal Area in California's Imperial Valley.[361] In 1993, California Energy sold 4,103 megawatt-hours of its geothermal electricity to Southern California Edison. This geothermal electricity offset 1,407 metric tons of carbon dioxide that otherwise would have been emitted by California's average generation mix.[362]

E. Conclusion

Renewables will be a key component of any national strategy to cut carbon dioxide emissions and reduce the threat of global climate change. Renewables costs have fallen steeply and are expected to drop further. Wind energy is already nearly cost-competitive with fossil generation—even when the high social and environmental costs of fossil fuels are not added to their prices. Photovoltaics are already cost-effective for certain transmission and distribution expansion applications, and are often the best option for off-grid generation. Solar thermal technologies continue to improve thanks to prudent federal government assistance, and offer promise as large-scale, centralized generation facilities. Geothermal is a proven technology yet to tap its vast geographic potential.

Endnotes

[1] Working Group III of the Intergovernmental Panel on Climate Change (IPCC) has been charged with assessing the economic costs of climate change. Some have argued for the use of "top-down" macroeconomic models, which look at aggregated statistical data, and claim that carbon dioxide emission controls could cost the U.S. economy 1 to 2 percent of GDP annually. On the other hand, "bottom-up" computer models find the opposite conclusion, that carbon dioxide emission controls could actually grow the economy by 1 to 2 percent annually through increased energy and economic efficiency, enhancing profitability, productivity, and new job creation.

Advocates for the "top down" models claim that it would be more cost-effective to delay implementation of carbon controls until current capital infrastructure and investments reach the end of their life-cycle. This argument, however, suffers in two respects. First, it fails to account for ecological reality: carbon dioxide continuously accumulates in the atmosphere, so emission reductions sooner are more valuable than reductions later. Second, it reflects an outmoded business philosophy. As discussed below, the businesses that will thrive in an increasingly competitive global economy are those that recognize the necessity of constant reinvestment in efficient production and productivity improvements. Energy efficiency investments will assist companies in becoming more productive and competitive, while helping the U.S. meet its international carbon dioxide reduction obligations. *See* Cutter Information, Corp., "IPCC Debates Economic Models," *Global Environmental Change Report*, Vol. VII, No. 17, pp. 1-3 (Arlington, MA: September 8, 1995); Quinn, B., "Boosting Productivity While Protecting the Environment," *Area Development*, pp. 39-44 (July 1995); *see also* Porter, M. and Van der Linde, C., "Green *and* Competitive: Ending the Stalemate," *Harvard Business Review*, pp. 120-134 (Boston, MA: September-October, 1995).

[2] Energy efficiency refers to obtaining greater benefits from a resource by investing in more efficient end-use products—such as compact fluorescent light bulbs, high-efficiency motors and drives, or more-efficient heating systems. Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace*, p. 6 (Washington, D.C: Alliance to Save Energy, January 1995).

[3] Geller, H. and Morris, H., *U.S. Carbon Emissions Continue to Climb in 1994*, p. 1 (Washington, D.C.: American Council for an Energy-Efficient Economy, June 1, 1995).

[4] Union of Concerned Scientists, Alliance to Save Energy, American Council for an Energy-Efficient Economy, and Natural Resources Defense Council, *America's Energy Choices: Investing in a Strong Economy and a Clean Environment* (Washington, D.C.: 1991); Geller, H., DeCicco, J., and Laitner, S., *Energy Efficiency and Job Creation: The Employment and Income Benefits from Investing in Energy Conserving Technologies*, p. ii (Washington, D.C.: American Council for an Energy-Efficient Economy, October 1992).

Investments in energy efficiency offer significant environmental improvements *and* economic gains. If the U.S. was to adopt the program laid out in *America's Energy Choices*, by the year 2010 America could:

- Reduce annual electricity generation by 27 percent;
- Decrease the need for new generating facilities by more than 50 percent;
- Reduce emissions of carbon dioxide in the utility sector by 33 percent and nitrogen oxides by 12 percent;
- Reduce the total amount paid for electricity by 18 percent (a savings of $50 billion in 1992 dollars); and
- Increase annual consumption of goods and services other than electricity by $45 billion.

All this could be accomplished without a loss of jobs or increased inflation, and with a cumulative savings of $211 billion off the nation's electric bill. Union of Concerned Scientists, et al., *America's Energy Choices: Investing in a Strong Economy and a Clean Environment* (Washington, D.C.: 1991); Moscovitch, E., "DSM in the Broader Economy: The Economic Impacts of Utility Efficiency Programs," *The Electricity Journal*, Vol. 7, No. 4, p. 15 (Seattle, WA: May 1994).

[5] Union of Concerned Scientists, et al., *America's Energy Choices: Investing in a Strong Economy and a Clean Environment* (Washington, D.C.: 1991).

[6] Other studies have also shown that the U.S. materials economy is only about 10 to 15 percent efficient—or even lower. Robert U. Ayres estimates that roughly 94 percent of the materials used in the U.S. manufacturing sector are converted to waste. This implies a net efficiency of only 6 percent. The vast volume of resource waste means a large environmental impact. It also means a higher cost of goods and services. Claassen, R., and Girifalco, L., "Materials for Energy Utilization," *Scientific American*, pp. 103-117 (October 1986); Ayres, R., "Industrial Metabolism," *Technology and Environment*, (Washington, D.C.: National Academy Press, 1987), as cited in Laitner, S., et al., *Environment and Jobs: The Employment Impact of Federal Environmental Investments*, Research Report No. 95-02, pp. 29-30 (Washington, D.C.: National Commission for Employment Policy, April 1995).

[7] A "quad" is one quadrillion British thermal units (Btu) of energy. The entire U.S. consumed 88.5 quads in 1994. Approximate equivalents to 1 quad include: (1) the amount of gasoline that will enable the average car to travel 170 billion miles; (2) the amount of energy in 6 billion cubic feet of hardwood; or (3) the primary energy that will meet the needs of 3 million average Americans for 1 year. United States Department of Energy, *Sustainable Energy Strategy: Clean and Secure Energy for a Competitive Economy*, p. 9 (Washington, D.C.: National Energy Policy Plan, U.S. Government Printing Office, July 1995); Rosenfeld, A., and Ward, E., "Energy Use in Buildings," *The Energy-Environment Connection*, Hollander, J., ed., p. 225 (Washington, D.C.: Island Press, 1992).

[8] United States Congress, Office of Technology Assessment, *Building Energy Efficiency*, OTA-E-518, p. 13 (Washington, D.C.: U.S. Government Printing Office, May 1992). Although part of the improvement in U.S. energy intensity can be attributed to structural shifts in the economy (such as from manufacturing to services) and interfuel substitution, approximately three-quarters was due to improved energy efficiency. Schipper, L., Howarth, R., and Geller, H., *United States Energy Use From 1973 to 1987: The Impacts of Improved Efficiency*, p. 458 (Washington, D.C.: American Council For an Energy-Efficient Economy, 1990).

[9] United States Department of Energy, *Sustainable Energy Strategy: Clean and Secure Energy For a Competitive Economy*, National Energy Policy Plan, ISBN 0-16-048183-X, p. 2 (Washington, D.C.: July 1995).

[10] United States Department of Energy, *Annual Energy Outlook 1992: With Projection Through 2010*, DOE/EIA-0383(92) (Washington, D.C.: Energy Information Administration, January 1992).

[11] United States Department of Energy, *Annual Energy Outlook 1995: With Projections to 2010*, DOE/EIA-0383(95), p. 11 (Washington, D.C.: Energy Information Administration, January 1995).

[12] Geller, H., DeCicco, J., and Laitner, S., *Energy Efficiency and Job Creation: The Employment and Income Benefits from Investing in Energy Conserving Technologies*, p. 45 (Washington, D.C.: American Council for an Energy-Efficient Economy, October 1992).

[13] Laitner, S., et al., *Energy Efficiency as an Investment in Ohio's Economic Future*, p. v (Washington, D.C.: American Council for an Energy-Efficient Economy, November 1994).

[14] Walker, K., et al., *Power Boosters: Ohio's Energy Efficiency Success Stories*, p. 7 (Washington, D.C.: Safe Energy Communication Council, 1995).

[15] Hagler Bailly Consulting, Inc., *The Global Market for Energy Efficiency*, pp. ii-iii (Arlington, VA: 1995).

[16] The global market for energy efficiency and environmental products and services is currently estimated to be $425 billion. Estimates of the scale of these markets vary widely, primarily because there is no agreement on which industries and technologies to include. The U.S. market for pollution avoidance and remediation alone is $134 billion per year. United States Department of Energy, "Energy Efficiency and Renewable Energy Benefits," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995); Laitner, S., et al., *Environment and Jobs: The Employment Impact of Federal Environmental Investments,* Research Report No. 95-02, pp. ii-iii (Washington, D.C.: National Commission for Employment Policy, April 1995).

[17] Porter, M., *The Competitive Advantage of Nations*, p. 652 (New York, NY: The Free Press, 1990), as cited in Laitner, S., et al., *Environment and Jobs: The Employment Impact of Federal Environmental Investments,* Research Report No. 95-02, p. 32 (Washington, D.C.: National Commission for Employment Policy, April 1995).

[18] United States Department of Energy, "Why Industrial Energy Use Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[19] The industrial sector includes manufacturing, mining, agriculture, and construction. Manufacturing is the largest component of the industrial sector, and accounts for about a quarter of total national electricity consumption. Including system losses in electric generation, manufacturing consumption was 20 quads in 1991, and accounted for 37 percent of total U.S. carbon dioxide emissions. Elliott, R. Neal, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector,* pp. iii, 2 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 1994); United States Department of Energy, "Why Industrial Energy Use Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[20] According to one market-based scenario, total energy use in the industrial sector could be reduced by 12 percent by 2010 and 18 percent by 2030 from baseline projections. *See America's Energy Choices*, pp. 65-66. The DOE has estimated that *technical* industrial energy savings potential in the year 2010 is 27 percent, and *achievable* industrial energy savings potential in the year 2010 is 13 percent. Congress' Office of Technology Assessment estimates that the potential industrial savings in the year 2015 is between 11 and 37 percent. An Oak Ridge National Laboratory report estimates that the cost-effective industrial fuel (non-electric) savings potential is 11 percent in the year 2010. *See* Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace,* p. 58, n. 21 (Washington, D.C.: Alliance to Save Energy, January 1995). The American Council for an Energy-Efficient Economy estimates that 14 to 38 percent of total electricity consumption can be saved through an orderly upgrade of equipment at the time of equipment failure, process modernization, or new construction. Process optimization and redesign would significantly increase this conservation potential. Elliott, R. Neal, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector,* p. iii (Washington, D.C.: American Council for an Energy-Efficient Economy, April 1994).

[21] More than 80 percent of the energy savings available to U.S. industry comes from electric motor systems improvements. Lighting and process improvements contribute slightly less than 10 percent. More than 33 percent of the energy savings available from motor systems improvements comes from the application of adjustable speed drives, with another 25 percent coming from improved drivetrain, electricity supply, and maintenance practices. Another 17 percent of electricity savings available from motors is estimated to come from installing more efficient motors. In fact, manufacturers spend about $30 billion annually to operate 40 million electric motors—which consume 70 percent of all energy in a typical manufacturing facility. These costs could be cut nearly in half with efficient motor systems. Elliott, R. Neal, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector,* pp. iii, 2 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 1994).

[22] Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace,* p. 18, (Washington, D.C.: Alliance to Save Energy, January 1995).

[23] Bartsch, C., and DeVaul, D., *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century,* p. 20 (Washington, D.C.: Northeast-Midwest Institute, 1994).

[24] United States Department of Energy, "Why Industrial Energy Use Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[25] Bartsch, C., and DeVaul, D., *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century,* p. 20 (Washington, D.C.: Northeast-Midwest Institute, 1994).

[26] Despite the size of the manufacturing sector's electricity expenditures, these expenditures only represent an average of 1.2 percent of the value of manufactured goods. In a few industries—such as aluminum and industrial gases—electricity purchases are more than 20 percent of the value of the manufactured products. In other industries like food processing, transportation equipment, and apparel, electricity purchases are less than 1 percent of the value of shipments. Elliott, R. Neal, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector,* pp. iii, 2 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 1994); United States Department of Energy, "Why Industrial Energy Use Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[27] *See* Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace,* p. 39, (Washington, D.C.: Alliance to Save Energy, January 1995).

[28] *Id.,* p. 40.

[29] *Id.,* p. 5.

[30] VOCs from 3M's process are below California's stringent standards. United States Department of Energy, "Dual Cure Coatings: 3M, St. Paul, Minnesota," *Case Studies*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[31] United States Department of Energy, "Dual Cure Coatings: 3M, St. Paul, Minnesota," *Case Studies*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[32] Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace,* p. 15, (Washington, D.C.: Alliance to Save Energy, January 1995).

[33] *Id.*

[34] The EADC/IAC recommendations for asphalt paving mixing companies include: insulate bare tanks, vessels, lines and process equipment; adjust (tune) burners for optimal air/fuel ratio; replace motors with energy-efficient motors; use higher efficiency, lower wattage lamps or ballasts in existing fixtures; use waste heat from hot flue gases to preheat combustion air; and install automatic stack dampers. *Id.,* p. 14.

[35] *Id.* After auditing ten smaller-sized asphalt manufacturing plants, the EADC/IAC program identified an average of more than $278,000 in annual energy-saving measures. The recommended energy-efficiency investments average a one-year payback and have saved 18,542 megawatt-hours of power, preventing about 11,116 metric tons of carbon emissions. *Id.*

[36] *Id.,* p. 33.

37 *Id.*

38 The six most common recommendations included: use higher efficiency, lower wattage lamps or ballasts in existing fixtures; install compressor air intakes in the coolest locations; eliminate leaks in lines and valves carrying compressed air or other gases; convert to more efficient light sources (e.g., fluorescent for incandescent) where acceptable; adjust (tune) burners for optimal air/fuel ratio; replace motors with energy-efficient motors; reduce operating time of equipment to the minimum required, and turn off during idle periods. *Id.*, p. 32.

39 *Id.*

40 United States Department of Energy, United States Environmental Protection Agency, *Metals Cleaning System Using CO_2 Cuts Grease, Protects Workers*, DOE/CH10093-339, DE94006940 (Washington, D.C.: National Industrial Competitiveness through Energy, Environment & Economics ($NICE^3$), September 1994).

41 *Id.*

42 Metal machining or processing companies could adapt the carbon dioxide dense-fluid system if they are currently using PCE or other chlorinated solvents to clean long rod, bar, and tube products, small machined parts, electronic components and connectors, or intricately-shaped products.

43 United States Department of Energy, U.S. Environmental Protection Agency, *Metals Cleaning System Using CO_2 Cuts Grease, Protects Workers*, DOE/CH10093-339, DE94006940 (Washington, D.C.: National Industrial Competitiveness through Energy, Environment & Economics ($NICE^3$), September 1994).

44 With the powder-paint system, primer coats are applied in powder form. Electrostatic attraction between the powder and the vehicle surface keeps the coating on the surface until the powder is polymerized in a bake oven at 325° F. The resulting surfaces are harder, and thus more resistant to chipping, and have a higher luster than liquid-painted vehicles. United States Department of Energy, United States Environmental Protection Agency, *Powder Paint System Improves Automobile Coatings, Boosts Environment*, DOE/CH10093-338, DE94006939 (Washington, D.C.: National Industrial Competitiveness through Energy, Environment & Economics ($NICE^3$), September 1994).

45 The facility is located in a "severe non-attainment" area for VOCs under the Clean Air Act, and must demonstrate a 15 percent reduction in emissions by 1996. United States Department of Energy, United States Environmental Protection Agency, *Powder Paint System Improves Automobile Coatings, Boosts Environment*, DOE/CH10093-338, DE94006939 (Washington, D.C.: National Industrial Competitiveness through Energy, Environment & Economics ($NICE^3$), September 1994).

46 *Id.*

47 In many Japanese plants, *every employee* is expected to minimize energy usage. Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace*, pp. 17, 58 n. 12 (Washington, D.C.: Alliance to Save Energy, January 1995). Other experts argue, however, that although Japanese industries are 25 percent less energy intensive, they pay more for their energy. Energy use times price may be about equal for the U.S. and Japan. Wolf, J., personal correspondence, December 5, 1995 (notes on file with the author).

48 New England Policy Council, *Power to Spare II: Energy Efficiency and New England's Economic Recovery*, p. 11 (Boston, MA: Conservation Law Foundation, et al., June 1992).

49 Elliott, R. Neal, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector*, pp. 13-14 (Washington, D.C.: American Council for an Energy-Efficient Economy, 1994); *see also* C. Bartsch and D. DeVaul, *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century*, pp. 50-57 (Washington, D.C.: Northeast-Midwest Institute, 1994); Romm, J., *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution*, p. 60 (New York, NY: Kodansha America, 1994).

50 This carbon dioxide reduction figure uses a DOE emissions factor of 0.662 metric tons/MWh for the state of Massachusetts. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

51 Walker, K., et al., *Power Boosters: Ohio's Energy Efficiency Success Stories*, pp. 11-12 (Washington, D.C.: Safe Energy Communication Council, 1995).

52 Hopkins, M., and Jones, T., *Getting in Gear: How Energy Efficiency Can Help Smaller Manufacturers Compete in the Global Marketplace*, p. 11 (Washington, D.C.: Alliance to Save Energy, January 1995).

53 Mar-Jar, Inc., and many manufacturers, do not divulge energy consumption information for competitive reasons. Obtaining carbon dioxide reduction data is thereby not possible. *Id.*

54 The EADC/IAC recommendations for poultry processors include: use higher efficiency, lower wattage lamps or ballasts in existing fixtures; replace motors with energy-efficient motors; adjust (tune) burners for optimal air/fuel ratios; insulate bare tanks, vessels, lines, and process equipment; install, upgrade, or repair insulation on steam lines; and repair and eliminate leaks in steam lines and valves. *Id.*, p. 10.

55 Walker, K., et al., *Power Boosters: Ohio's Energy Efficiency Success Stories*, pp. 20-21 (Washington, D.C.: Safe Energy Communication Council, 1995).

56 *Id.*

57 *Id.*

58 The positive employment and income results of efficiency investments are due primarily to the relatively low number of jobs in the energy sectors (coal, oil, and gas extraction, fuel refining, and electric and gas utilities) compared to the economy as a whole. Conserving energy reduces the energy bills paid by consumers and businesses, thereby enabling greater purchases of non-energy goods, equipment, and services. The result is a shift of economic activity away from energy supply industries and towards sectors of the economy that employ more workers per dollar received.

Less than 10 percent of the net jobs created are associated with direct investment in efficiency measures while more than 90 percent are associated with re-spending energy bill savings. The largest absolute increase in jobs is in the construction, retail trade and services industries, as these sectors install energy-efficiency measures and gain new business orders from the re-spending of energy bill savings.

Productivity improvements in the oil and gas extraction industries are likely to lead to a reduction of 200,000 jobs in this sector by 2010. Individual companies in the fossil-fuel sector may be able to reduce adverse jobs impacts by diversifying into the energy efficiency and renewable energy fields. Geller, H., DeCicco, J., and Laitner, S., *Energy Efficiency and Job Creation: The Employment and Income Benefits from Investing in Energy Conserving Technologies*, pp. iii-iv (Washington, D.C.: American Council for an Energy-Efficient Economy, October 1992).

59Romm, J., *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution*, pp. 152-153 (New York, NY: Kodansha America, 1994).

60 *Id.*

61 U.S. Environmental Protection Agency, and U.S. Department of Energy, *The Climate Wise Program Opportunities Assessment Guide: Turning Energy Efficiency and Environmental Performance Into a Corporate Asset*, Version 1.0, p. 17 (Washington, D.C.: October 1995).

62 *Id.*

63 The Metal Casting Center, *Turning the Corner at Crane-Washington*, pp. ii-iii, 1-18 (Cedar Falls, Iowa: University of Northern Iowa, 1995).

64 Romm, J., *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution,* pp. 42-43 (New York, NY: Kodansha International, October 1994).

65 *Id.*

66 *Id.*

67 United States Department of Energy, "Why Utility Energy Use Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

68 *Id.*

69 United States Department of Energy, *Annual Energy Outlook 1995 With Projections to 2010*, DOE/EIA-0383(95), p. 11 (Washington, D.C.: Energy Information Administration, January 1995).

70 United States Department of Energy, *Annual Energy Review 1992,* DOE/EIA-0384(92) (Washington, D.C.: Energy Information Administration, June 1993).

71 Rosenfeld, A., and Ward, E., "Energy Use in Buildings," *The Energy-Environment Connection,* Hollander, J., ed., p. 225 (Washington, D.C.: Island Press, 1992).

72 DSM programs improve the efficiency with which customers use electricity, and also affect the timing of that use (e.g., by shifting it away from high-cost, peak times). Utilities run such programs for two primary reasons. One is to improve customer service. The second is to acquire resources that, just like power plants, can meet customer energy-service needs. DSM programs are often less expensive and environmentally cleaner than power plants. Hirst, E., and Eto, J., *Justification for Electric-Utility Energy-Efficiency Programs,* ORNL/CON-419, LBNL-37593, p. 1 (Oak Ridge, TN: Oak Ridge National Laboratory, August 1995).

73 These include four states that decouple profits from sales volume (CA, MT, NY, and WA), and six states that have other unconditional lost-revenue recovery mechanisms (CT, MA, NH, OR, PA, and VT). Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment*, p. 14 (Washington, D.C.: American Council for and Energy-Efficient Economy, April 22, 1994).

74 The Electric Power Research Institute is a utility-funded organization in Palo Alto, California.

75 Hadley, S., and Hirst, E., *Utility DSM Programs from 1989 through 1998: Continuation or Crossroads?,* ORNL/CON-405 (Oak Ridge, TN: Oak Ridge National Laboratory, February 1995), cited in Hirst, E., and Eto, J., *Justification for Electric-Utility Energy-Efficiency Programs,* ORNL/CON-419, LBNL-37593, p. 1 (Oak Ridge, TN: Oak Ridge National Laboratory, August 1995).

76 *Id.*

77 This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

78 Hirst, E. and Eto, J., *Justification for Electric-Utility Energy-Efficiency Programs,* ORNL/CON-419, LBNL-37593 (Oak Ridge, TN: Oak Ridge National Laboratory, August 1995); Geller, et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment,* pp. 15-16 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 22, 1994), citing Hirst, E., *Electric-Utility DSM-Program Costs and Effects: 1991 to 2001* (Oak Ridge, TN: Oak Ridge National Laboratory, May 1993). This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

79 Miller, P., *Presentation Before CPUC Full Panel Hearing on Restructuring*, R. 94-04-031, p. 2 (September 8, 1995). Net benefits from the 1990 through 1992 programs totaled $1.4 billion (D.93-09-078), while net benefits from 1993 were $0.4 billion (D.94-12-021). Utility applications for 1994 estimate net benefits also at $0.4 billion (applications 95-04-038, 95-04-041, 95-04-046, and 95-04-050).

80 Hirst, E., Cavanagh, R., & Miller, P., *The Future of DSM in a Restructured U.S. Electricity Industry* (publication forthcoming, 1995). This is the full, amortized cost to the utilities of a kilowatt-hour at the meter—with no credit for peak savings—and is considerably lower than any other energy resource available in California. Miller, P., *Presentation Before CPUC Full Panel Hearing on Restructuring*, R. 94-04-031, p. 2 (September 8, 1995).

81 Hirst, E., Cavanagh, R., & Miller, P., *The Future of DSM in a Restructured U.S. Electricity Industry*, p. 2 (publication forthcoming, 1995).

82 The Results Center, *Pacific Gas & Electric: Direct Assistance Programs*, Profile #75, p. 2 (Aspen, CO: IRT Environment, Inc., 1993).

83 This carbon dioxide reduction data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

84 The Results Center, *Pacific Gas & Electric: Model Energy Communities Program*, Profile #81, p. 2 (Aspen, CO: IRT Environment, Inc., 1994).

85 This carbon dioxide reduction data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

86 The Results Center, *Southern California Edison: CFB and CFL Manufacturer's Rebates*, Profile #113 (Aspen, CO: IRT Environment, Inc., 1994).

87 This carbon dioxide reduction data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

88 The Results Center, *Sacramento Municipal Utility District: Comprehensive Municipal DSM*, Profile #91 (Aspen, CO: IRT Environment, Inc., 1994).

89 This carbon dioxide reduction data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-

0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[90] United States Department of Energy, "Sacramento Municipal Utility District," *Case Studies*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[91] The Results Center, *California Energy Commission: Energy Partnership Program*, Profile #64, p. 2 (Aspen, CO: IRT Environment, Inc., 1993).

[92] This carbon dioxide reduction data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[93] Northwest Power Planning Council data, November 9, 1995. Carbon dioxide reduction data uses a DOE emission factor of 0.107, which is the lowest emission factor in the Northwest region (for the state of Oregon). Thus the figure understates the actual carbon dioxide reduction amount. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995); state electric generation capacity data is from Freedman, M., *Renewable Energy Sourcebook* (Washington, D.C.: Public Citizen, April 18. 1995).

[94] U.N. General Assembly, "United Nations Framework Convention on Climate Change," A/AC.237/18 (Part II)/Add.1 and A/AC.237/18 (Part II)/Add.1/Corr.1 (United Nations, 1992). With the fiftieth ratification filed with the Convention's Secretariat, the FCCC entered into force on March 21, 1994. See note 116 and accompanying text.

[95] The Results Center, *Portland Energy Office: Multifamily Energy Savings Program*, Profile #104 (Aspen, CO: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses a DOE emissions factor for Oregon of 0.107 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[96] The Results Center, *The City of Ashland: Comprehensive Conservation Programs*, Profile #115 (Aspen, CO: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses a DOE emissions factor for Oregon of 0.107 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[97] The Results Center, *Bonneville Power Administration: WaterWise Program*, Profile #85 (Aspen, CO: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses an average emission factor for Washington and Oregon of 0.132 metric tons/MWh, weighted by the electric generation capacity of each state, and assumes efficiency measures were evenly distributed between the two states. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995); state electric generation capacity data is from Freedman, M., *Renewable Energy Sourcebook* (Washington, D.C.: Public Citizen, April 18, 1995).

[98] Jordan, J., and Nadel, S., *Industrial Demand-Side Management Programs: What's Happened, What Works, What's Needed,* pp. 22-24 (Washington, D.C.: American Council for an Energy-Efficient Economy, March 1993). Carbon dioxide reduction data uses a DOE-derived average emission factor for WA, OR, ID and MT of 0.213 metric tons/MWh, weighted by the electric generation capacity of each Pacific Northwest state, and assumes efficiency measures for the aluminum smelters are distributed evenly among the four states. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.:Energy Information Administration, June 1995); state electric generation capacity data is from Freedman, M., *Renewable Energy Sourcebook* (Washington, D.C.: Public Citizen, April 18, 1995). Bonneville is currently transferring responsibility for most conservation investments to its retail utility customers. Cavanagh, R., personal correspondence (New York, NY: Natural Resources Defense Council, December 5, 1995) (notes on file with the author).

[99] The Results Center, *Puget Sound Power & Light: Commercial & Industrial Electricity Conservation Service,* Profile #74 (Aspen, CO: IRT Environment, Inc., 1993). Carbon dioxide reduction data uses a DOE emissions factor for Washington State of 0.139 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[100] The Results Center, *Seattle City Light: Comprehensive Municipal DSM,* Profile #103 (Aspen, CO: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses a DOE emission factor for Washington State of 0.139 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[101] Conservation Law Foundation, *Power to Spare II: Energy Efficiency and New England's Economic Recovery*, p. 7 (Boston, MA: June 1992).

[102] This carbon dioxide reduction data uses a DOE emission factor for Massachusetts of 0.662 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[103] Coakley, S., and Schlegel, J., *Comparing Electric Utility DSM Planning and Evaluation Estimates in Massachusetts: Are We Getting What We Planned For?*, p. 303 (Chicago, IL: International Energy Program Evaluation Conference, August 23, 1995).

[104] The Results Center, *New England Electric System: Design 2000,* Profile #92 (Aspen, CO: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses a DOE-derived, average emission factor for Massachusetts, Rhode Island and New Hampshire of 0.574 metric tons/MWh, weighted by the electric generation capacities of these New England states, and assumes efficiency measures are installed evenly among the three states. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995); electric generation capacity data is from Freedman, M., *Renewable Energy Sourcebook* (Washington, D.C.: Public Citizen, April 18, 1995).

[105] The Results Center, *Burlington Electric Department: Comprehensive Municipal DSM,* Profile, #98 (Aspen, Co.: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses a DOE emission factor for Vermont of 0.072 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[106] New York Public Service Commission, *Energy Conservation Fact Sheet* (Pace University Center for Environmental Legal Studies, September 1994).

[107] Consolidated Edison, corporate data (December 19, 1995). Carbon dioxide reduction data uses an emission factor of 0.470 metric tons/MWh for the state of New York. United States Department of Energy, Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[108] Consolidated Edison, corporate data (December 19, 1995). Carbon dioxide reduction data uses an emission factor of 0.470 metric tons/MWh for the state of New York. United States Department of Energy, Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[109] Public Service Commission of Wisconsin, *The Future of Wisconsin's Electric Power Industry: Environmental Impact Statement, Volume I*, PSC Docket 05-EI-114, p. 99 (October 1995). Carbon dioxide reduction data uses an emission factor of 0.609 metric tons/MWh for the state of Wisconsin. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[110] Carbon dioxide reduction data uses a DOE emission factor of 0.609 metric tons/MWh for the state of Wisconsin. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[111]The Results Center, *Madison Gas & Electric: Residential Lighting Program Niagara Mohawk Power Corporation: Commercial/Industrial Lighting Rebate,* Profile #69 (Aspen, CO: IRT Environment, Inc., 1993). Carbon dioxide reduction data uses an emission factor of 0.609 metric tons/MWh for the state of Wisconsin. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[112] Sustainable Energy Budget Coalition, *Penny Wise, Pound Fuelish: Congressional Energy Budget Proposals, a State-By-State Analysis,* pp. 4-5 (Tacoma Park, MD: June 1, 1995). These savings figures do not count the reduction in pollution, oil imports, and threat of climate change reduced by federal efficiency investments. The same Congressional Research Service study found that the U.S. annual trade deficit would be $16 billion larger were it not for these federal investments. *Id.*

[113] United States Environmental Protection Agency and United States Department of Energy, *The Climate Wise Partnership Agreement and Action Plan*, pp. 1-6 (Washington, D.C.: EPA Office of Policy, Planning and Evaluation, DOE Office of Energy Efficiency and Renewable Energy, 1994).

[114] *Id.*, p. 7.

[115] *Id.*

[116] U.N. General Assembly, "United Nations Framework Convention on Climate Change," A/AC.237/18 (Part II)/Add.1 and A/AC.237/18 (Part II)/Add.1/Corr.1 (United Nations, 1992).

[117] Clinton, President William J., and Gore, Vice President Albert, Jr., *The Climate Change Action Plan*, DOE/PO-0011-2, p. 5 (Washington, D.C.: October, 1993).

[118] United States Department of Energy, *Energy for Today and Tomorrow: Investments for a Strong America,* Fiscal Year 1996 Budget-in-Brief, p. 13 (Washington, D.C.: Office of Energy Efficiency & Renewable Energy, 1995); Hirst, E., & Eto, J., *Justification for Electric-Utility Energy-Efficiency Programs*, ORNL/CON-419, LBNL-37593, p. 19 (Oak Ridge, TN: Oak Ridge National Laboratory, August 1995).

[119] Federal agencies are directed to reduce their energy consumption by 30 percent, compared to their 1985 consumption levels, by 2005. Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776 (1992), 42 U.S.C.A. §§ 13201-556 (West Supp. 1994) (EPAct). Executive Order 12902 assigned responsibility for coordinating agency compliance efforts to the DOE's FEMP program.

[120] Sustainable Energy Budget Coalition, *Penny Wise, Pound Fuelish: Congressional Energy Budget Proposals, a State-By-State Analysis,* p. 24 (Tacoma Park, MD: June 1, 1995).

[121] *Id.*

[122] United States Department of Energy, *Energy for Today and Tomorrow: Investments for a Strong America,* Fiscal Year 1996 Budget-in-Brief, p. 16 (Washington, D.C.: Office of Energy Efficiency & Renewable Energy, 1995).

[123] Sustainable Energy Budget Coalition, *Penny Wise, Pound Fuelish: Congressional Energy Budget Proposals, a State-By-State Analysis,* pp. 23-24 (Tacoma Park, MD: June 1, 1995); United States Department of Energy, *Energy for Today and Tomorrow: Investments for a Strong America,* Fiscal Year 1996 Budget-in-Brief, p. 13 (Washington, D.C.: Office of Energy Efficiency & Renewable Energy, 1995).

[124] Sustainable Energy Budget Coalition, *Penny Wise, Pound Fuelish: Congressional Energy Budget Proposals, a State-By-State Analysis,* p. 24 (Tacoma Park, MD: June 1, 1995).

[125] *Id.*, pp. 19-20.

[126] Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776 (1992), 42 U.S.C.A. §§ 13201-556 (West Supp. 1994) (EPAct). Title XVI of EPAct, titled "Global Climate Change," set forth a number of targets designed to promote a national least-cost energy strategy, including:
(a) A 30 percent increase in energy efficiency by 2010, based upon 1988 levels;
(b) A 75 percent increase in the use of renewable energy by 2005, based upon 1988 levels;
(c) A reduction in U.S. oil consumption from 40 percent to 35 percent of total energy use by 2005.

[127] There are important reasons to restructure the present vertically-integrated utilities, and spin off generation, transmission, and distribution as separate legal entities–including conflicts of interest among the three functions. For example, the business purpose of generation companies will be to maintain as much market share as possible within current retail service territories. On the other hand, distribution companies in a restructured industry—which provide hook-up services to end users— will seek to influence the generation portfolios that serve many, if not all, of their customers. Distribution companies will be in the energy services business, and will seek to provide a mix of energy resources as demanded by end-use customers. The portfolio provided by distribution companies may well include a mix that maximizes energy efficiency and renewables over more polluting generation sources. If the distribution companies help in any way to select the winners in an increasingly competitive generation marketplace, distribution's ownership of some of the generation competitors is a fundamental conflict of interest. Divestiture is perhaps the only solution. The utility industry would ultimately be comprised of independent electricity distribution, transmission, and generation companies. *See* Cavanagh, R., *Restructuring for Sustainability: Energy-Efficiency Solutions in the New Electric Services Industry*, pp. 8-9 (New York, NY: Natural Resources Defense Council, October 16, 1995).

[128] Hirst, E., and Hadley, S., "The DSM Sky Hasn't Fallen Yet," *The Electricity Journal*, Vol. 7, No. 10, p. 79 (Seattle, WA: December 1994).

[129] Hirst, E., and Eto, E., *Justification for Electric-Utility Energy-Efficiency Programs*, ORNL/CON-419, LBNL-37593, pp. 48-49 (Oak Ridge, TN: Oak Ridge National Laboratory, August 1995).

[130] United States Department of Energy, "Why Industrial Energy Use Matters," *Fact* Sheet, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995); Bartsch, C., and DeVaul, D., *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century,* p. 3 (Washington, D.C.: Northeast-Midwest Institute, 1994).

[131] Industrial DSM programs typically offer direct rebates for the installation of energy-efficient measures related to the following: motors, lighting, HVAC systems, steam traps, adjustable speed drives (ASDs), and compressed air systems.

[132] Bartsch, C., and DeVaul, D., *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century,* pp. 5, 57-62 (Washington, D.C.: Northeast-Midwest Institute, 1994).

[133] *Id.* Carbon dioxide reduction data uses an emission factor of 0.662 metric tons/MWh for the state of Massachusetts. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[134] Bartsch, C., and DeVaul, D., *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century,* pp. 5, 57-62 (Washington, D.C.: Northeast-Midwest Institute, 1994). Carbon dioxide reduction data uses an emission factor of 0.662 metric tons/MWh for the state of Massachusetts. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[135] Nadel, S., and Jordan, J., *Designing Industrial DSM Programs That Work,* pp. 16-17 (Washington, D.C.: American Council for an Energy-Efficient Economy, December 1993); Jordan, J., and Nadel, S., *Industrial Demand-Side Management Programs: What's Happened, What Works, What's Needed,* pp. 36-38 (Washington, D.C.: American Council for an Energy-Efficient Economy, March 1993); carbon dioxide reduction data uses an emission factor of 0.609 metric tons/MWh for the state of Wisconsin, provided by the United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[136] Bartsch, C., and DeVaul, D., *Utilities and Manufacturers: Pioneering Partnerships and Their Lessons for the 21st Century,* pp. 62-66 (Washington, D.C.: Northeast-Midwest Institute, 1994). Carbon dioxide reduction data uses an emission factor of 0.139 metric tons/MWh for the state of Washington. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[137] U.S. buildings consumed about 31.5 "quads" in 1989. Rosenfeld, A., and Ward, E., "Energy Use in Buildings," *The Energy-Environment Connection,* Hollander, J., ed., p. 223 (Washington, D.C.: Island Press, 1992).

[138] *Id.*

[139] United States Department of Energy, "Why Building Efficiency Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[140] United States Congress, Office of Technology Assessment, *Building Energy Efficiency*, OTA-E-518, p. 3 (Washington, D.C.: U.S. Government Printing Office, May 1992).

[141] Commercial buildings used 12.9 quads of energy at a cost of $68 billion in 1989. Despite growth in the number of energy-intensive commercial buildings (the commercial building stock, as measured by total square footage, grew more than 50 percent from 1970 to 1989), and increases in air conditioning and other equipment, energy intensity (energy use per square foot per year) stayed flat in the commercial sector from 1970 to 1990. Improved energy-efficiency technologies helped dampen the growth in energy use through improved windows and shells, greater use of ceiling and wall insulation, more efficient heating, ventilation and air-conditioning (HVAC) equipment, better lighting systems, and other technologies. Future commercial energy use, despite expected continued expansion of commercial office space, is also projected to remain flat. Investments in commercial building technologies with a positive net present value to the consumer could cut building energy use from 29.7 quads today to 28 quads by 2015, corresponding to an annual energy savings of 14 quads by 2015—worth $80 billion at today's energy prices. United States Congress, Office of Technology Assessment, *Building Energy Efficiency,* OTA-E-518, pp. 3, 21-32 (Washington, D.C.: U.S. Government Printing Office, May 1992).

[142] Americans consumed 16.8 quads of energy in residential buildings (including single-family dwellings) in 1989. Space heating is responsible for almost half of total residential energy use, followed by water heating, refrigerators and freezers, air conditioning, and lights. Although total residential energy use increased from 1970 to 1989, primarily due to a 45 million increase in U.S. population over that period, energy intensity (energy consumed per household per year) actually *decreased* by 15 percent in the same period. The reasons for the decrease include:

- Retrofitting older homes with energy-efficiency technologies. From 1983 to 1988, about 26 million owner-occupied U.S. households added storm windows and/or doors, and 17 million added insulation.
- Greater use of energy-efficient building practices in newer houses. New houses built in 1985 installed far more insulation than did houses built in 1973, including 46 percent greater R-value (insulation heat retention) in ceilings, 20 percent more R-value in exterior walls, 60 percent more R-value in floor insulation, and 68 percent fewer single-pane windows.
- Improved equipment and appliance efficiency.

Assuming the recent decrease in residential energy intensity continues, an annual residential consumption of 15.6 quads by 2010 is possible. United States Congress, Office of Technology Assessment, *Building Energy Efficiency*, OTA-E-518, pp. 3, 15, 18, 31 (Washington, D.C.: U.S. Government Printing Office, May 1992).

[143] Individual homeowners also often fail to make efficiency investments because of a variety of market barriers, including uncertainty regarding the savings that will result from specific measures, uncertainty regarding how long they will own or occupy the home, uncertainty regarding the resale market value of the efficiency improvements, and lack of capital. In addition, renters are often responsible for utility bills but are not in a position to make capital improvements. Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment*, p. 13 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 22, 1994).

[144] United States Department of Energy, "Why Building Efficiency Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[145] United States Department of Energy, "Why Building Efficiency Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[146] Romm, J., and Browning, W., *Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design,* p. 1 (Snowmass, CO: Rocky Mountain Institute, December 1994).

[147] *Id.,* pp 8-9.

[148] *Id.*

[149] *Id.,* p 10.

[150] *Id.*

[151] *Id.*

[152] *Id., p. 11.*

[153] Geller, H. and Nadel, S., *Implications of the Energy Policy Act of 1992 for Utility Demand-Side Management Efforts* (Washington, D.C.: American Council for an Energy-Efficient Economy, March 1993).

[154]This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[155] Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776 (1992), 42 U.S.C.A. §§ 13201-556 (West Supp. 1994).

[156] United States Department of Energy, *Sustainable Energy Strategy: Clean and Secure Energy for a Competitive Economy,* p. 26 (Washington, D.C.: National Energy Policy Plan, U.S. Government Printing Office, July 1995).

[157] Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment*, p. 13 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 22, 1994).

[158]This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[159] Howard, B., and Prindle, W., *Better Building Codes For Energy Efficiency*, p. iii (Washington, D.C.: The Alliance to Save Energy, September 1991).

[160] Adoption of building codes, to be effective, must be supplemented with compliance and enforcement measures, including (1) training and education for designers, builders, owners, and code officials, (2) enforcement support, including inspections, and (3) quality assurance and evaluation. Smith, L. and Nadel, S., *Energy Code Compliance*, pp. 22-24 (Washington, D.C.: American Council for an Energy-Efficient Economy, August 1995).

[161] Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment*, p. 13 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 22, 1994).

[162] Howard, B., and Prindle, W., *Better Building Codes For Energy Efficiency*, p. iii (Washington, D.C.: The Alliance to Save Energy, September 1991). The 1995 MEC code was recently adopted by the Building Officials and Code Administrators, Inc. (BOCA) as the energy-conservation provisions for the National Building and Mechanical Codes. This action replaces a reference to the MEC or ASHRAE Standards 90A and 90B as compliance alternatives. Those states (primarily in the Midwest, Mid-Atlantic, and Northeast) that refer in their state codes to BOCA standards will remove the reference to the ASHRAE standards (which are more than 15 years old and have been superseded by newer standards referenced in the newest MEC). Thus, the latest Model Energy Code will be included in the next published edition of the BOCA codes. Several states, including Virginia, Oklahoma, and New Jersey, by law adopt the newest edition of the BOCA codes when they become available. Building Codes Assistance Project, *Announcing a BCAP Success: BOCA Adopts the Latest Edition of the Model Energy Code,* p. 1 (Washington, D.C.: 1995).

[163] United States Department of Energy, "Why Building Efficiency Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[164] These gains are typically tiny compared to the cost of employees, which is greater than the total energy and operating costs of a building. A 1990 national survey of large office buildings measured average electricity costs at $1.53 per square foot. Maintenance and repairs add another $1.37 per square foot. Labor, on the other hand, costs on average $130 per square foot—72 times the energy costs. Thus, an increase of 1 percent in productivity can nearly offset a company's entire annual energy expenditures. Romm, J., and Browning, W., *Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design,* p. 3 (Snowmass, CO: Rocky Mountain Institute, December 1994).

[165] Productivity is measured by Joe Romm, Special Assistant for Policy and Planning to the Deputy Secretary of Energy, in terms of production rate, quality of production, and changes in absenteeism. These productivity factors can be improved by fewer distractions from eye strain or poor thermal comfort, and similar variables. *Id.*

[166] United States Department of Energy, "Why Building Efficiency Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[167] The energy-efficiency investments were not undertaken for energy *conservation*, but rather to increase energy *efficiency*. Conservation implies reduced services; energy efficiency means providing the same or better energy services using less energy. In general, building efficiency upgrades provide more pleasing light, more reliable production, and greater comfort and control. Romm, J., *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution,* pp. 72-73 (New York: Kodansha America, 1994).

[168] *Id.,* pp. xv-xviii.

[169] Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776, 42 U.S.C.A. §§ 13201-556 (West Supp., 1994) (EPAct).

[170] United States Department of Energy, "Forrestal Relighting Initiative," *Case Studies,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[171] The Results Center, *The City of Phoenix: Energy Management Program*, Profile Brief #118 (Basalt, CO: IRT Environment, 1994). Carbon dioxide reduction data uses a DOE emission factor for Arizona of 0.362 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[172] United States Environmental Protection Agency, *Green Lights: Fourth Annual Report*, EPA 430-R-95-004, pp. 24-25 (Washington, D.C.: Office of Air and Radiation, June 1995).

[173] Geller, H. and Nadel, S., "Market Transformation Strategies to Promote End-Use Efficiency," *Annual Review of Energy and Environment* 19, p. 308 (Washington, D.C.: American Council for an Energy-Efficient Economy, 1994).

[174] United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 3 (Washington, D.C.: July 1993).

[175] Car removals assume an annual average carbon dioxide emission per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year). Forty million cars is equivalent to about a quarter of the U.S. fleet. *See* United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 3 (Washington, D.C.: Office of Air and Radiation, July 1993); United States Environmental Protection Agency, *Green Lights: Fourth Annual Report,* EPA 430-R-95-004, p. 2 (Washington, D.C.: Office of Air and Radiation, June 1995).

[176] United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 3 (Washington, D.C.: July 1993).

[177] The overall savings potential as a fraction of end use is 20 to 40 percent, and lighting represents more than 15 percent of total electricity consumption in some industry groups like textiles, printing, apparel, and furniture. Elliott, R. Neal, *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector,* p. iv (Washington, D.C.: American Council for an Energy-Efficient Economy, April 1994).

[178]Green Lights participants include major corporations in the oil, pharmaceutical, retail, and industrial sectors, hotels and restaurants, newspapers and cable networks, universities and school districts, hospitals and insurance companies, financial institutions and real estate firms, federal, state and local government agencies and offices, as well as nonprofit groups. EPA provides a package of networking, technical, and marketing tools, at no cost, that are designed to ensure that lighting upgrades will result in the greatest possible energy savings. Included is a financing registry to help participants manage the up-front costs of converting their lighting, including an extensive database of utility-sponsored financial assistance and a directory of energy service companies (ESCos) that finance lighting-efficiency upgrades through leasing, shared savings, guaranteed savings, and other financing techniques. United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, pp. 8-9 (Washington, D.C.: July 1993).

[179] *Id.*

[180]This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[181] This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995); United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 17 (Washington, D.C.: July 1993).

[182] United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 17 (Washington, D.C.: July 1993).

[183] Lawrence Berkeley National Laboratory, *From the Lab to the Marketplace* (Berkeley, CA: Energy & Environment Division, 1994).

[184] Romm, J., *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution*, pp. 74-75 (New York: Kodansha America, 1994); Laitner, S., *Energy Efficiency Investments as a Productivity Strategy for the United States: An Overview*, pp. 4-5 (Alexandria, VA: Economic Research Associates, June 1995). Carbon reduction data uses a DOE emission factor for Washington of 0.139 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[185] Romm, J., and Browning, W., *Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design,* pp. 6-7 (Snowmass, CO: Rocky Mountain Institute, 1994).

[186] *Id.*, p. 10.

[187] *Id.* Carbon dioxide reduction data derives from a DOE emission factor for Ohio of 0.820 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[188] Romm, J., and Browning, W., *Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design,* p. 6 (Snowmass, CO: Rocky Mountain Institute, 1994).

[189] "United Airlines Energy Savings Soar With Retrofit," *Lighting Management & Maintenance*, Vol. 23, No. 6, p. 8 (Princeton Junction, NJ: CMA Publications, July 1995). The carbon dioxide reduction data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[190] CMA Publications, "Sica Electrical to Retrofit the World Trade Center," *Lighting Management & Maintenance*, Vol. 23, No. 6, p. 8 (Princeton Junction, NJ: July 1995). Carbon dioxide reduction data uses a DOE emission factor for New York of 0.470 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[191] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Massachusetts of 0.662 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[192] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Florida of 0.587 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average

carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[193] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Washington of 0.139 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[194] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[195] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Tennessee of 0.606 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[196] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Oregon of 0.107 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[197] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Texas of 0.704 metric tons/MWh. United States Department of Energy. *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[198] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Oklahoma of 0.758 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[199] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Washington, D.C. of 1.192 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[200] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Virginia of 0.502 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[201] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[202] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Utah of 0.903 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[203] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for New York of 0.470 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[204] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Hawaii of 0.687 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[205] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Indiana of 0.985 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[206] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[207] United States Environmental Protection Agency, Green Lights Profile (Washington., D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Massachusetts of 0.662 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[208] United States Environmental Protection Agency, Green Lights Profile (Washington, D.C.: Atmospheric Pollution Prevention Division, 1995). Carbon dioxide reduction data uses a DOE emission factor for Pennsylvania of 0.583 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[209] Unfortunately, the House and Senate have each passed legislation that would prohibit DOE from conducting any buildings-oriented rulemaking, including HERS. Verdict, M., "DOE Proposes New Guidelines for Home Energy Ratings Based on Five-Star Program," *Alliance Update*, p. 8 (Washington, D.C.: Alliance to Save Energy, Summer 1995).

[210] *Id.*

[211] The rating system evaluates these home-efficiency measures: compact fluorescent lights; water heater tank wraps; ceiling, floor, and pipe insulation; efficient refrigerators and freezers; high-efficiency space and water heating equipment; air leakage reduction and controls. The Results Center, Inc., *Energy Rated Homes of America: Uniform Energy Rating System,* Profile Brief #90, p. 2 (Basalt, CO: IRT Environment, 1994).

[212] *Id.* Increased availability of uniform ratings would enable lenders and utilities to expand their energy loan programs much more rapidly and help increase consumer demand.

[213] A one-star home includes increased heating and cooling efficiencies, somewhat higher insulation levels, and improved shading coefficients on windows (solar screens).

[214] Two-star homes include reduced air infiltration, improved shading techniques, higher equipment efficiencies, and higher insulation values.

[215] Three-star homes typically take the total design of the home into account for maximum energy advantage, as well as optimum efficiencies. These ratings apply to both all-electric and multifuel homes. The Alliance to Save Energy, "A Star-Quality Rating Program in Austin,"*Reaching For the Stars: Shining Examples of Success in Energy-Efficient Housing,* p. 19 (Washington, D.C.: March 1991).

[216] *Id.*

[217] This carbon dioxide reduction figure uses a DOE emissions factor of 0.704 for the state of Texas. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[218] Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment*, p. 10 (Washington, D.C.: American Council for an Energy-Efficient Economy, April 22, 1994).

[219] To be cost-effective, the total cost of the energy-efficient improvements (including maintenance costs) must be less than the total present value of the energy saved over the useful life of the improvements. United States Department of Housing and Urban Development, *Single Family Loan Production—Expansion of the Energy Efficient Mortgage Program*, Mortgagee Letter 95-46 (Washington, D.C.: Office of the Assistant Secretary for Housing, Federal Housing Commissioner, October 6, 1995).

[220] For new construction, the energy improvements must be over and above those required for compliance with the current FHA energy conservation standards for new construction (which are the CABO 1992 Model Energy Code). *Id.*

[221] *Id.*

[222] Verdict, M., *Selling Home Buyers on Energy Loan Programs*, p. 2 (Washington, D.C.: Alliance to Save Energy, 1995).

[223] *Id.*

[224] *Id.*

[225] Rosenfeld, A., and Ward, E., "Energy Use in Buildings," *The Energy-Environment Connection*, Hollander, J., ed., pp. 235-36 (Washington, D.C.: Island Press, 1992).

[226] Honeywell, Inc., "Performance Contracting," *Smart Building Energy Management*, forthcoming.

[227] *Id.* Carbon dioxide reduction data uses a DOE emission factor for Washington of 0.139 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995). Car removals assume annual average carbon dioxide emissions per car of 4.54 metric tons, based on 22 pounds of CO_2 per gallon, a U.S. fleet average of 19.2 mpg, 15.6 gallons per tank, 300 miles traveled per tank, and 8,800 average miles driven per year (29.33 tanks of gasoline per year).

[228] United States Department of Energy, *Sustainable Energy Strategy: Clean and Secure Energy for a Competitive Economy,* pp. 26-27 (Washington, D.C.: National Energy Policy Plan, U.S. Government Printing Office, July 1995).

[229] Lawrence Berkeley National Laboratory, *From the Lab to the Marketplace* (Berkeley, CA: Energy & Environment Division, 1994).

[230] McMahon, J., Turiel, I., and Geller, H., "National Impacts of Appliance Standards," *Energy and Buildings* (forthcoming).

[231] This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[232] The program was crafted by the U.S. Environmental Protection Agency, the Natural Resources Defense Council, the American Council for an Energy-Efficient Economy, Pacific Gas and Electric, and Southern California Edison.

[233] The average rated electricity consumption of new refrigerators declined from about 1,725 kilowatt-hours per year in 1972 to around 685 kilowatt-hours per year in 1993. Geller, H. and Nadel, S., "Market Transformation Strategies to Promote End-Use Efficiency," *Annual Review of Energy and Environment* 19, p. 305 (Washington, D.C.: American Council for an Energy-Efficient Economy, 1994).

[234] Nadel, S., et al., *Emerging Technologies to Improve Energy Efficiency in the Residential & Commercial Sectors*, p. 16 (Washington, D.C.: American Council for an Energy-Efficient Economy, February 1993).

[235] United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 15 (Washington, D.C.: July 1993).

[236] This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[237]The Results Center, *Super Efficient Refrigerator Program*, Profile Brief #106 (Basalt, CO: IRT Environment, 1994). This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[238] The Results Center, *Super Efficient Refrigerator Program*, Profile Brief #106 (Basalt, CO: IRT Environment, 1994).

[239] Rosenfeld, A., and Ward, E., "Energy Use in Buildings," *The Energy-Environment Connection,* Hollander, J., ed., p. 242 (Washington, D.C.: Island Press, 1992).

[240] United States Department of Energy, "Low-E Windows," *Case Studies*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[241] United States Environmental Protection Agency, *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention,* EPA 430-K-93-001, p. 15 (Washington, D.C.: July 1993).

[242] Clinton, President W., and Gore, Vice President A., *The Climate Change Action Plan*, DOE/PO-0011-2, p. 17 (Washington, D.C.: October 1993); United States Department of Energy, "Why Transportation Energy Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[243] Clinton, President W., and Gore, Vice President A., *The Climate Change Action Plan*, DOE/PO-0011-2, p. 17 (Washington, D.C.: October 1993).

[244] Fulkerson, W., *et al.*, "Energy Technology R & D: What Could Make a Difference?" ORNL-6541/V1, Part 1: Synthesis Report, p. 20 (Oak Ridge, TN: Oak Ridge National Laboratory, May 1989).

[245] Brown, M. and Vaughan, K., *Science and Technology for a Sustainable Energy Future: Accomplishments of the Energy Efficiency and Renewable Energy Program at Oak Ridge National Laboratory*, ORNL/CON-410, p. 35 (Oak Ridge, TN: Oak Ridge National Laboratory, March 1995); United States Department of Energy, "Why Should We Care About Sustainable Energy?" *Fact Sheet*, p. 2 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[246] United States Department of Energy, "Why Transportation Energy Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[247] United States Department of Energy, Office of Technical and Financial Assistance, *America's Best: Outstanding State Energy Grant Projects*, DOE/CH 10093-149, DE92010586, p. 10 (Golden, CO: National Renewable Energy Laboratory, August 1992).

[248] United States Department of Energy, "Why Transportation Energy Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[249] United States Department of Energy, *Sustainable Energy Strategy: Clean and Secure Energy For a Competitive Economy,* National Energy Policy Plan, ISBN 0-16-048183-X, p. 20 (Washington, D.C.: July 1995). Six criteria pollutants addressed in the Clean Air Act are related to transportation sources: (1) ground level ozone (smog precursors such as volatile organic compounds (VOCs) and oxides of nitrogen (NOx)), (2) carbon monoxide, (3) particulate matter less than 10 microns in diameter (PM-10), (4) nitrogen dioxide, (5) sulfur dioxide, and (6) lead.

[250] United States Department of Energy, "Why Transportation Energy Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[251] Walsh, M., "Motor Vehicles and Global Warming," *Global Warming: The Greenpeace Report,* Leggett, J., ed., p. 261 (Oxford University Press: 1990). Each gallon of gasoline consumed emits about 22 pounds of carbon dioxide. *Id.* at 284.

[252] National Academy of Sciences, *Policy Implications of Greenhouse Warming*, p. 11 (Washington, D.C.: National Academy Press, 1991).

[253] Walsh, M., "Motor Vehicles and Global Warming," *Global Warming: The Greenpeace Report,* Leggett, J., ed., pp. 261-62 (Oxford University Press: 1990).

[254] Sperling, D., "Gearing Up For Electric Cars," *Issues in Science and Technology*, Vol. XI, No. 2, p. 34 (Dallas, TX: National Academy of Sciences, Winter 1994-95).

[255] United States Department of Energy, "Why Transportation Energy Matters," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[256] United States Department of Energy, Office of Technical and Financial Assistance, *America's Best: Outstanding State Energy Grant Projects*, DOE/CH 10093-149, DE92010586, p. 10 (Golden, CO: National Renewable Energy Laboratory, August 1992).

[257] Natural Resources Defense Council, Inc., *Cooling the Greenhouse: Vital First Steps to Combat Global Warming,* p. 31 (Washington, D.C.: 1989).

[258] DeCicco, J., and Ross, M., "Improving Automotive Efficiency," *Scientific American*, p. 55 (December 1994).

[259] *Id.*

[260]Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment,* p. 5 (Washington, D.C.: American Council For an Energy-Efficient Economy, April 22, 1994).

[261] Because total vehicle miles driven increased by 90 percent since 1970, total fuel used by automobiles and light trucks has increased by 45 percent over the 20-year period. *Trends in Transportation Energy Use and Emissions,* Background Paper, p. 2 (November 1994).

[262] *Id.* In the same period, however, the number of miles traveled per gallon increased by 45 percent.

[263] McCosh, D., "Lean, Mean, and Green: A Low-Cost, High-Tech Approach to Safety and Lower Emissions," *Popular Science*, p. 65 (New York, NY: Times-Mirror, November 1995).

[264]Geller, H., et al., *Bridging the Gap: Initiatives to Achieve President Clinton's Climate Commitment,* p. 5 (Washington, D.C.: American Council For an Energy-Efficient Economy, April 22, 1994), citing DeCicco, J., *Savings from CAFE: Projections of the Future Oil Savings from Light Vehicle Fuel Economy Standards* (Washington, D.C.: American Council For an Energy-Efficient Economy, May 1992).

[265] Super-emitters tend to be older vehicles, but some are relatively new vehicles with poorly maintained engines, defective emission-control equipment, or emission controls that have been tampered with. Sperling, D., *Future Drive: Electric Vehicles and Sustainable Transportation*, p. 16 (Washington, D.C.: Island Press, 1995).

[266] Kallen, R., et al., *Components of a Model Accelerated Vehicle Retirement Program*, p. 27 (Chicago, IL: Environmental Law and Policy Center, March 27, 1995). AVR programs must be designed such that net emissions are actually reduced. Some past programs have awarded pollution permits too liberally, having failed to determine whether the older, scrapped vehicles had been recently driven, and how much.

[267] Remote sensing is considered by some as the cutting edge of AVR. A remote sensor projects a beam of infrared light across the road to a detector. The exhaust from a passing car alters the beam, and the resulting fluctuations measure carbon monoxide and nitrogen oxide emissions. Kallen, R., et al., *Components of a Model Accelerated Vehicle Retirement Program*, p. 28 (Chicago, IL: Environmental Law and Policy Center, March 27, 1995).

[268] Brown, M. and Vaughan, K., *Science and Technology for a Sustainable Energy Future: Accomplishments of the Energy Efficiency and Renewable Energy Program at Oak Ridge National Laboratory*, ORNL/CON-410, pp. 42-43 (Oak Ridge, TN: Oak Ridge National Laboratory, March 1995).

[269]Sperling, D., *Future Drive: Electric Vehicles and Sustainable Transportation*, p. 18 (Washington, D.C.: Island Press, 1995).

[270] *Id.*, pp. 18-19.

[271] United States Department of Energy, "Why Transportation Energy Matters," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[272] United States Department of Energy, *Sustainable Energy Strategy: Clean and Secure Energy For a Competitive Economy,* National Energy Policy Plan, ISBN 0-16-0481833-X, p. 20 (Washington, D.C.: July 1995).

[273] United States Department of Energy, *Annual Energy Outlook 1994 With Projections to 2010,* DE94-005938, p. 19 (Oak Ridge, TN: January 1994).

[274] Companies subject to the ZEV requirements are "major" automakers selling more than 35,000 vehicles per year in California. The companies include General Motors, Ford, Toyota, Chrysler, Honda, Nissan, and Mazda. In 2003, the threshold will drop to 3,000 sales per year, which will affect most European companies and smaller Japanese companies. Sperling, D., *Future Drive: Electric Vehicles and Sustainable Transportation*, pp. 38-39 (Washington, D.C.: Island Press, 1995).

An important lure for all these companies is the ability to sell ZEV credits. For each vehicle sold, the California Air Resources Board will provide the company with a ZEV credit. Credits can be sold to any of the Big Seven manufacturers. Because the fine for not selling a ZEV is $5,000, and the loss per vehicle is expected to be greater than $5,000 per vehicle initially, the Big Seven should be willing to pay up to $5,000 for each vehicle credit. The trading of ZEV credits could be attractive to all concerned. It allows a company such as General Motors to meet part (or all) of its ZEV responsibilities without paying an embarrassing fine and without incurring large losses. And it provides small, cash-strapped electric vehicle companies with a substantial cash subsidy for every vehicle sold, even small neighborhood electric cars. *Id.,* p. 43.

[275] *Id.,* p. 39.

[276] Flavin, C., and Lenssen, N., *Power Surge: Guide to the Coming Energy Revolution,* Worldwatch Environmental Alert Series, p. 197 (New York, NY: W.W. Norton, 1994).

[277] Flanigan, J., "Chance at a Clean Start: Zero-Emission Car Mandate Needs to Be More Flexible," *The Los Angeles Times*, p. D6 (June 7, 1995).

[278] United States Department of Energy, "Programs Targeted For Urban Centers and Municipalities," *Fact Sheet,* p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[279] More electric vehicles does not necessarily mean more power plants. Batteries can be recharged during off-peak hours when excess generating capacity is available. The prospect of recharging at night presents electric utilities with an opportunity to operate more efficiently by allowing them to draw power from otherwise idle capacity. Sperling, D., *Future Drive: Electric Vehicles and Sustainable Transportation*, p. 58 (Washington, D.C.: Island Press, 1995).

[280] *Id.,* pp. 55-56.

[281] Zetsche, D., "The Automobile: Clean and Customized," *Scientific American*, Vol. 273, No. 3, p. 105 (New York, NY: September 1995). The vehicle battery market is not yet mature. The most expensive component in the electric driveline is the battery. Currently available lead-acid batteries last less than two years and 20,000 miles and do not store enough energy to power a full-size vehicle very far or fast. But major improvements are expected, especially as the California ZEV mandate approaches in 1998. *See Id.,* pp. 48-49.

[282] Flavin, C., and Lenssen, N., *Power Surge: Guide to the Coming Energy Revolution,* Worldwatch Environmental Alert Series, pp. 199-200 (New York, NY: W.W. Norton, 1994).

[283] *Id.,* p. 203. Researchers see a potential to increase the energy storage capacity of lead-acid batteries by 50 percent or more, while other research teams are seeking to adapt the more efficient but costlier nickel-cadmium and lithium batteries used in computers and other electronic devices. A 1994 study by the California Air Resources Board suggests that battery technology continues to advance rapidly, and that by the end of this decade new batteries may double the 60- to 100-mile range typical of today's electric cars. In the longer run, still lower costs and greater storage capacities are within reach. *Id.,* pp. 211-12.

[284] GM test-drivers have driven the car at over 170 miles per hour—a record for electric cars. *Id.,* p. 203. An early Impact prototype accelerated to 60 mph in eight seconds, faster than Nissan's 300ZX sports car. *Popular Science* described it as "possibly the best-handling and best-performing small car that GM has ever turned out." McCosh, S., "We Drive the World's Best Electric Car," *Popular Science*, Vol. 244, No. 1, pp. 52-56 (January 1994).

[285] Flavin, C., and Lenssen, N., *Power Surge: Guide to the Coming Energy Revolution,* Worldwatch Environmental Alert Series, p. 203 (New York, NY: W.W. Norton, 1994).

[286] Ford Taurus emissions are based on a 50,000-mile urban/suburban testing cycle. Impact emissions are based on the current California electricity generation mix. *Id.,* pp. 206-07.

[287] Calstart, Inc., "PIVCO and CALSTART Roll Out $10,000 Electric Commuter Car," *The CALSTART Connection,* Vol. 3, No. 4, p. 1 (Burbank, CA: August-October 1995).

[288] Solectria Corporation, *Sunrise Specifications*, corporate marketing materials (Wilmington, MA: 1995).

[289] Zetsche, D., "The Automobile: Clean and Customized," *Scientific American*, Vol. 273, No. 3, p. 105 (New York, NY: September 1995).

[290] Flavin, C., and Lenssen, N., *Power Surge: Guide to the Coming Energy Revolution,* Worldwatch Environmental Alert Series, p. 205 (New York, NY: W.W. Norton, 1994).

[291]The cost of fuel-cell vehicles is sensitive to the type of fuel used. The life-cycle costs of fuel-cell cars powered by solar hydrogen may be somewhat greater than those of comparable gasoline cars, while fuel cells powered by natural gas probably would be cheapest. Sperling, D., *Future Drive: Electric Vehicles and Sustainable Transportation*, p. 93 (Washington, D.C.: Island Press, 1995).

[292] *Id.,* p. 89.

[293] Solar hydrogen is hydrogen made by electrolytically splitting water using solar cells. The technology is still expensive. However, Joan Ogden and Robert Williams of Princeton University have argued that rapid advances in solar technology make inexpensive solar electricity a possibility. They predict that the cost of solar hydrogen in the early years of the next century, including all distribution and retail mark-ups (but not taxes), could be between $2.25 and $3.25 per gasoline-equivalent gallon. Because fuel cells are more than twice as energy efficient as internal combustion engines, the relatively high cost of solar hydrogen is, from the vehicle user's perspective, more than halved, bringing fuel costs within a commercially viable range.

The ideal place for producing solar hydrogen is in sunny locations such as the American Southwest. If all the cars and trucks in the U.S. were fueled with hydrogen in 2010, only 1 percent of U.S. deserts—equivalent to 0.1 percent of the total U.S. land area—would be needed to produce the hydrogen. *Id.,* p. 90.

[294] *Id.,* pp. 85-86.

[295] Atwood, S., "Hydrogen Fuel Cell Vehicles to be Tested in Palm Desert," *AQMD Advisor*, Vol. 3, No. 1, p. 5 (Diamond Bar, CA: South Coast Air Quality Management District, November 1995).

[296] Greene, D., *Commercial Air Transport Energy Use and Emissions: Is Technology Enough?* DE-AC05-84OR21400, pp. 3, 21-22 (Oak Ridge, TN: Oak Ridge National Laboratory, August 3, 1995).

[297] Warren, W., "Why Success in St. Louis?" *TR News 180*, pp. 22-26 (September-October 1995).

[298] Freedberg, M., "Community Green Line Initiative," *Opportunities in Neighborhood Technology*, pp. 1-12 (Chicago, IL: Center for Neighborhood Technology, 1995).

[299] Renewables also include hydroelectric and biomass. Substantial potential for hydroelectric capacity expansion exists in the U.S., particularly in the Northeast. Although biomass provides some 5 percent of U.S. total energy use (including electricity generation, space heating with wood, and transportation fuels such as ethanol and methanol), biomass employs the combustion process, creating air emissions that include carbon dioxide. Biomass feedstock management can offset these emissions by sequestering carbon dioxide as feedstocks grow, and the use of biomass in place of fossil fuels can involve a net decrease in overall carbon dioxide emissions.

[300] Hamrin, J., and Rader, N., *Investing in the Future: A Regulator's Guide to Renewables*, p. 7 (Washington, D.C.: The National Association of Regulatory Utility Commissioners, February 1993).

[301] In June 1995, Northern States Power announced a winning levelized bid price of 3 cents per kilowatt-hour for development of a 100-megawatt wind project. Swezey, B., and Wan, Y., *The True Cost of Renewables: An Analytic Response to the Coal Industry's Attack on Renewable Energy*, NREL/TP-462-20032, p. 14, n. 8 (Golden, CO: National Renewable Energy Laboratory, October 1995), citing National Renewable Energy Laboratory, *State Renewable Energy News* (Summer 1995).

[302] An analysis of energy futures performed by Shell International notes that renewables costs will continue to fall as production increases. The key question for renewables is not whether costs will fall, but "the speed at which market opportunities will appear, to enable renewables to move down their cost curves." Grunwald, E.J., *Energy in the Long Term* (Shell International Petroleum Co., Ltd., undated), cited in Swezey, B., and Wan, Y., *The True Cost of Renewables: An Analytic Response to the Coal Industry's Attack on Renewable Energy*, NREL/TP-462-20032, p. 2, n. 1 (Golden, CO: National Renewable Energy Laboratory, October 1995).

[303] Public Utility Regulatory Policies Act of 1978, Pub. L. No. 95-617, 92 Stat. 3117 (1978), 16 U.S.C. § 2601, *et seq.* (1982) (PURPA).

[304] Avoided costs are measured as the amount the utility would have had to spend to provide the capacity and energy itself. Utilities are able to pass through the cost of purchased power to ratepayers, creating an incentive for utilities to engage in demonstration and commercialization of renewables. PURPA demonstrated that competition in generation is both viable and beneficial and has led to an expanding renewable energy sector.

[305] Rosenzweig, R., "The Federal Interest in Electric Restructuring," *Public Utilities Fortnightly,* Vol. 133, No. 20, p. 18 (Vienna, VA: November 1, 1995).

[306] Internationally, India has committed to install 2,000 megawatts of renewable energy by 2000, and China has featured renewable energy in its Agenda 21—a plan developed to achieve the objectives established by the Framework Convention on Climate Change. India and China alone will account for 35 percent of incremental electricity demand between 1993 and 2010, requiring $450 billion in capital. Because research and development has driven down their costs, renewable technologies will have an opportunity to compete against conventional technologies in international markets. *Id.*

[307] Capacity factor is the amount of load achieved by operating a given generation source, and is a measure of dependability. Solar- and wind-based projects, without storage, typically have capacity factors of 20 to 30 percent because they operate only when the sun shines or the wind blows. Swezey, B., and Wan, Y., *The True Cost of Renewables: An Analytic Response to the Coal Industry's Attack on Renewable Energy*, NREL/TP-462-20032, pp. 2-4 (Golden, CO: National Renewable Energy Laboratory, October 1995).

[308] When power from intermittent resources is not available, other generators on the system are called on to supply the power. At low renewables penetration levels, this situation is much like the normal utility system response to load fluctuations. At higher renewables penetration levels, a utility might have to provide additional dispatchable capacity to compensate for both normal load fluctuations and the output variations of the intermittent renewables generators. Research shows that intermittent penetration levels above 10 percent are entirely feasible, with any technical limits being a function of the specific utility system characteristics.

[309] Wind project developers have been signing contracts to deliver electricity at prices as low as 4 cents per kilowatt-hour in a contract's first year, and wind developer Zond Systems just signed a contract for 3 cents per kilowatt-hour levelized over 30 years.

Geothermal and small-scale hydro plants can produce electricity for between 4.5 and 7 cents per kilowatt-hour. Even the more expensive photovoltaics systems (which convert sunlight to electricity) have seen costs fall to around $7 a watt for grid-connected systems, down from $30 a watt for experimental systems in the early 1980s, and now produce electricity for between 25 and 50 cents a kilowatt-hour. Williams, S., and Bateman, B., "Despite Improved Performance and Lower Costs, U.S. Renewable Power in a Slump," News Release, p. 2 (Washington, D.C.: Investor Responsibility Research Center, August 2, 1995).

[310] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 4, 30 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[311] *Id.*, p. 4.

[312] The Massachusetts Supreme Court and an administrative law judge in New York recently struck down those states' externality rules or values, and Nevada is reconsidering its values for environmental externalities. California says it also plans to reform or repeal its externality values in the near future. *Id.*, pp. 4-5.

[313] *Id.*, p. 5.

[314] *Id.*

[315] *Id.*, p. 255.

[316] Gipe, P., "Wind Energy's Declining Costs," *Solar Today*, Vol. 9, No. 6, p. 23 (Boulder, CO: The American Solar Energy Society, November/December 1995).

[317] The cost of operating and maintaining wind turbines is about half a cent per kilowatt-hour. This is half the cost of coal and nuclear plant operations, maintenance, and fuel, and about one-third the cost of that for gas-fired plants. The installed capacity cost of new turbines in commercial-scale projects of 10 to 20 megawatts ranged from $800 to $1,000 per kilowatt in 1994. The American Wind Energy Association expects that the industry will reduce installed costs to around $750 per kilowatt by the year 2000. *Id.*, pp. 23-24, 262.

[318] *Id.*, p. 24. The difference in cost between decommissioning nuclear power plants and wind power plants is substantial, but often ignored. For example, decommissioning the damaged Unit 2 reactor at Three Mile Island will cost more than $1 billion when completed, nearly as much as it cost to build the plant. Overall, decommissioning nuclear plants will cost from $0.3 billion to as much as $3 billion per 1000-megawatt reactor in 1985 dollars, or $300 to $3,000 per kilowatt. Wind plants, in comparison, are sustainable, and can be upgraded indefinitely. If decommissioning were necessary for some reason, it would cost about $3,000 to $5,500 per turbine, or $30 to $55 per kilowatt—at least six times less than nuclear. The turbine's salvage value would likely offset much of this. *Id.*

[319] A 50-megawatt wind facility typically is completed in 18 months. *Id.*, p. 24. A study by Los Alamos Laboratory found that "utilities could afford to pay as much as four times more in overnight construction costs for five-year lead-time plants than for 15-year lead-time plants." According to Oak Ridge National Laboratory, building a series of power plants with short lead times would cut the price of electricity 18 percent over the 15-year period considered, or 1.3 cents per kilowatt hour, relative to building one 600-megawatt coal-fired power plant over four years. *Id.*, pp. 24-25.

[320] *Id.*, p. 25. Michael DeAngelis and Sam Rashkin of the California Energy Commission's research and development office performed an analysis of the hidden costs associated with all electric generation sources, and concluded that oil combustion, nuclear fission, fuel cells, and coal have among the highest costs, while efficiency, wind, biomass, hydroelectric and solar thermal electric are among the lowest-cost technologies.

[321] *Id.* A survey by the National Renewable Energy Laboratory (NREL) found that competitive bidding in most states has a "systematic bias against renewables" because of the emphasis on using "proven" (traditional) technologies, the undervaluation of environmental costs, and the exclusion of fuel-price uncertainty for fossil fuel plants.

[322] By de-emphasizing the price volatility of fossil fuels, the cost of energy for conventional energy sources appears lower in early years than that for technologies with high capital costs but low fuel costs, like those of renewables. *Id.*

[323] This carbon dioxide reduction data uses a national average for electricity, given the actual fuel share in 1993, of 0.6332 metric tons per megawatt-hour (MWh). In the future, avoided emissions will depend on the actual displacement of future and/or existing plants. Laitner, S., Economic Research Associates (Arlington, VA: December 5, 1995).

[324] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, p. 255 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[325] This figure derives from a 1990 Battelle Pacific Northwest Laboratory study, which assumed that, in windy areas of the 37 states most suitable for utility-scale wind development, 90 percent of range lands, 70 percent of agricultural land, and 50 percent of forest ridge crests would be available for energy production, while urban areas and environmentally protected lands would be excluded. Wind development is compatible with other uses, and preserves land for rural uses; much of the range and agricultural lands still would be available for grazing and farming because wind power development (including roads, turbine and transformer pads, and service buildings) occupies only 5 to 10 percent of the total land area for a project. *Id.*, pp. 259, 272.

[326] *Id.*, p. 260.

[327] Kenetech is confident enough in its wind resource data to offer power output guarantees for wind-power plants that it is selling to the Sacramento Municipal Utility District and PacifiCorp. *Id.*

[328] McGraw Hill, "Kenetech," *125 Independent Power Companies: Profiles of Industry Players and Projects*, p. 72 (1994).

[329] Tax incentives available to the wind industry include a 10-year energy production tax credit of 1.5 cents per kilowatt-hour (inflation-adjusted) for wind projects brought on-line between 1994 and 1999 and a five-year depreciation for wind equipment. Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 262-63, 266 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[330] This carbon dioxide data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[331] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 284-86 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[332] This carbon dioxide data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[333] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 281-83 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[334] United States Department of Energy, "Energy Pioneer: FloWind," *Fact Sheet*, p. 1 (Washington, D.C.: Office of Energy Efficiency and Renewable Energy, 1995).

[335] California Energy Commission Performance Data, cited in Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 283-84 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[336] This carbon dioxide data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[337] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 304-09 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[338] California Energy Commission Performance Data, cited in Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 308-09 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[339] This carbon dioxide data uses a DOE emissions factor for California of 0.343 metric tons/MWh. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[340] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, p. 391 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[341] *Id.*

[342] Chandler, D., "Solar, Wind Units Seen as Boon to Ratepayers," *The Boston Globe* (August 8, 1995); Oppenheim, J., *Renewable Energy Technology Analysis*, p. 1 (Brookline, MA: Pace University School of Law, Energy Project Center, August 16, 1995).

[343] Solar Energy Industries Association data, cited in Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, p. 391 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[344] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, p. 391 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[345] Fully 26 percent of SMUD customers are willing to pay a premium for PV power generated on their own rooftops. Seventy percent were willing to participate in a "green pricing" program in which they would pay more on their monthly utility bills so that SMUD could establish a "Clean Energy" program.

[346] The Results Center, *Sacramento Municipal Utility District: Solar Photovoltaics Program*, Profile #111 (Aspen, CO: IRT Environment, Inc., 1994). Carbon dioxide reduction data uses a DOE emissions factor of 0.343 for California. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

[347] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 437-39 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[348] Parabolic troughs consist of long rows of concentrators that are curved in only one dimension, forming troughs. The troughs are mounted on a single-axis tracking system that tracks the sun from east to west. They are lined with a reflective surface that focuses the sun's energy onto a pipe located along the trough's focal line. A heat transfer fluid is circulated through the pipes and then pumped to a central storage area, where it passes through a heat exchanger. The heat is then transferred to a working fluid, usually water, which is flashed into steam to drive a conventional steam turbine. *Id.*, p. 451.

[349] Without favorable tax treatment, a parabolic trough system would generate electricity for about 17 cents per kilowatt-hour today. *Id.*

[350] Central receiver technology consists of a fixed receiver mounted on a tower surrounded by a large array of mirrors, known as heliostats. The heliostats track the sun and reflect its rays onto the receiver, which absorbs the heat. Within the receiver, a fluid absorbs the receiver's heat energy and then is transported from the receiver to a turbine generator or a storage tank. *Id.*, p. 454.

[351] *Id.*, pp. 454-55.

[352] *Id.*, p. 467.

[353] Parabolic dish generating systems consist of parabolic-shaped point-focus concentrators that reflect solar energy onto a receiver mounted at the focal point. Parabolic dishes typically use dozens of curved reflective panels made of glass or laminated films, mounted on a structure that tracks the sun. When the concentrated sunlight hits the receiver, it is either directly utilized by a heat engine, or used to heat a fluid that is transmitted to a central engine. *Id.*, p. 457.

[354] *Id.*, pp. 457-58.

[355] *Id.*, pp. 185-86.

[356] *Id.*, p. 185.

[357] *Id.*, pp. 185-86.

[358] In 1994, production stood at about 1,250 megawatts. Field operators expect an additional 50 percent decline over the next 20 years, to about 600 megawatts. Although industry estimates that only about 5 percent of the field's geothermal heat has been tapped, the decline stems from depletion of fluid in the field. Over-building has contributed to the fluid decline, as well as the practice of reinjecting only about 20 percent of the fluid used in production (the other 80 percent is evaporated in cooling towers). By adding fluid from external sources, including reinjecting most of the produced fluid and modifying power plant design, The Geysers could supply at least several hundred megawatts of electricity for another 50 years. *Id.*, p. 188.

[359] *Id.*

[360] Weisgall, J., California Energy Company, Inc., personal correspondence (Washington, D.C.: December 11, 1995) (notes on file with the author).

[361] Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, pp. 210-13 (Washington, D.C.: Investor Responsibility Research Center, 1995).

[362]Southern California Edison power purchase data from Williams, S., and Bateman, B., *Power Plays: Profiles of America's Independent Renewable Electricity Developers*, p. 216 (Washington, D.C.: Investor Responsibility Research Center, 1995). This carbon dioxide reduction data is derived from a DOE emissions factor of 0.343 metric tons/MWh for California. United States Department of Energy, *Voluntary Reporting of Greenhouse Gases: Reporting Form and Instructions*, Form EIA-1605EZ, OMB No. 1905-0194, Appendix F ("Adjusted Electricity Emission Factors by State") (Washington, D.C.: Energy Information Administration, June 1995).

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