# The Path to Carbon-Dioxide-Free Power:

## Switching to Clean Energy in the Utility Sector

A Study for

**World Wildlife Fund**

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April 2003

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**Acknowledgments**

We wish to thank Monica DeClerq, Rebecca Eaton, Lara Hansen, Katherine Silverthorne and Kathleen Sullivan of WWF for their assistance on this report.

We would like to thank colleagues at the American Council for an Energy Efficient Economy and the Union of Concerned Scientists with whom Tellus has worked on similar analyses in the recent past and from which this work has benefited.

We wish to thank the following people who gave their expertise in reviewing this study:

Mark Bernstein of Rand Corporation, Thomas R. Casten of Private Power LLC, Ken Colburn of Northeast States for Coordinated Air Use Management (NESCAUM), Dan Lashof of Natural Resources Defense Council, Scott Sklar of The Stella Group, and Marika Tatsutani of NESCAUM.

*Review of the report does not imply endorsement of its contents. Information and opinions contained in this report are the views of the authors and of WWF.*

## 1 Executive Summary

The burning of fossil fuels—oil, gas and coal—emits carbon dioxide ($CO_2$) into the atmosphere where it builds up, blankets the earth and traps heat, causing global warming. The earth's atmosphere now contains more $CO_2$ than it has at any time during the last several hundred millennia—leading to impacts on coral reefs, arctic ice and other important habitats around the globe. The United States must dramatically reduce its emissions of heat-trapping carbon dioxide to levels that will prevent worst-case threats to humans—such as a radical shift in ocean currents or sea levels, permit ecosystems to adapt naturally, protect food production; and ensure that economic development is sustainable. To achieve this goal, emissions from the power sector, currently responsible for more 40 percent of annual U.S. $CO_2$ emissions, must be dramatically reduced. Fortunately, there are technologies available today affecting both electricity consumption and production that could bring about this change.

This report examines the policies and measures needed to accelerate the use of those technologies and dramatically reduce U.S. heat-trapping gas emissions by 2020. The goal is to set the nation on the path to achieving zero-carbon electricity by mid-century, as part of the crucial effort to stabilize atmospheric concentrations of heat-trapping gases in this century at levels that will avert dangerous climate change.

This report explores a broad set of national policies to increase energy efficiency, accelerate the adoption of renewable energy technologies and shift energy use to more efficient power systems while *reducing* the electricity bills of consumers and businesses. Similar and complementary policies can and have been be undertaken by states and cities. The focus is on the electric generation sector but also addresses major electricity-using sectors, including industrial facilities as well as residential and commercial buildings.

This portfolio of policies and measures would bring overall economic *benefits* to the United States. In 2020, the net savings to households and businesses are more than $80 billion a year. Contrary to the claims of some, taking action today is more economically beneficial than delaying. Action by the United States on global warming is inevitable given the growing scientific consensus and commitment by the rest of the industrial world to take action now. Thus, the sooner the nation takes action, the sooner we provide certainty to consumers, businesses and utility executives, the better off the entire nation will be both environmentally and economically. The sooner we use efficiency technologies and clean renewable energy, the sooner we will lower energy bills and reduce pollution. Delay locks in another generation of inefficient capital stock, raises future costs and undercuts our ability to maintain the leadership in the clean energy technologies and businesses that will be one of the job-creating engines of international trade in this century.

*Policies and measures*

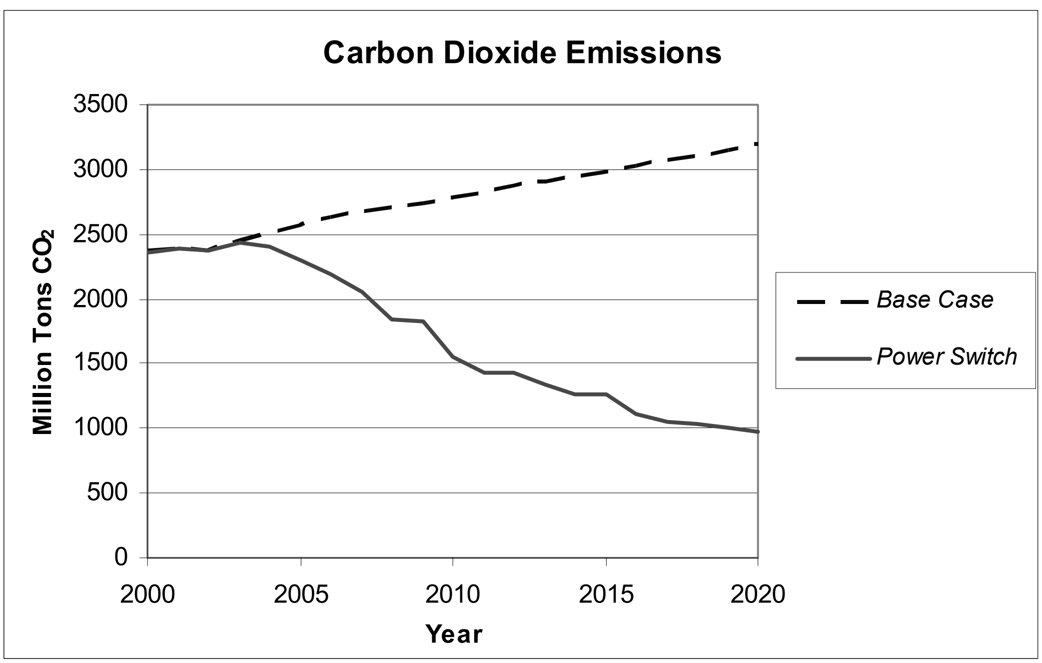
The policies considered for the industrial sector are aimed at utilizing more of the vast potential for cogeneration of heat and power and at improving energy efficiencies at industrial facilities through technical assistance, financial incentives and expanded research and development (R&D) programs to encourage cost-effective emissions reductions. The policies for residential and commercial buildings include strengthened codes for building energy consumption, new appliance efficiency standards, tax incentives and a national public benefits fund to support investments in high-efficiency products and expanded R&D into energy-efficient technologies. The policies considered for the electric generation sector included a market-oriented "renewable portfolio standard" (RPS) and a cap on pollutant emissions of sulfur dioxide, nitrogen oxides, mercury and carbon dioxide. We are labeling all of these policies taken together the *PowerSwitch! Case*.

*Results*

The policies in the *PowerSwitch! Case* provide the same or better electricity services to businesses and homeowners by 2020 relative to the business-as-usual *Base Case*—while requiring 25 percent less electricity generation. This is accomplished primarily through increased efficiency by electricity consumers. Relative to current levels, use of non-hydro renewable energy—wind, biomass, solar and geothermal—increases by a factor of 12 by 2020 in the *PowerSwitch! Case*, whereas in the *Base Case* it increases by a factor of less than 2.5.

The reduction in electricity-related $CO_2$ emissions is more dramatic than the reduction in electricity consumption because of the shifts toward renewable energy, lower-carbon fuels (especially from coal to gas) and more efficient power generation (cogeneration). In the *Base Case,* electricity-related carbon dioxide grows by more than 30 percent from 2000 to 2020. In the *PowerSwitch! Case*, the United States promptly begins to reduce these emissions, as seen in Figure ES-1. By 2020, emissions are about 60 percent below current levels. And this is all achieved without the price of $CO_2$ rising above $15 a ton.

**Figure ES-1 Modeled Carbon Dioxide Emissions**



In addition to heat-trapping gas emission reductions, the set of policies in the *PowerSwitch! Case* also reduce criteria air pollutants that harm human health, cause acid rain and smog, poison rivers and streams and adversely affect agriculture, forests, water resources and buildings. In particular, we assume the United States puts in place a cap and trade system that reduces sulfur dioxide ($SO_2$) emissions from current emissions of 11 million tons to a cap of 2.87 million tons in 2010 and 2.27 million tons in 2016; cuts emissions of nitrogen oxides ($NO_x$) from power plants from current emissions of 5 million tons to a cap of 1.548 million tons in 2008; and cuts mercury emissions from power plants from current emissions of 48 tons to a cap of 5 tons in 2008.

The complete *PowerSwitch!* package achieves dramatic emissions reductions in electric sector pollution while providing a net economic benefit to the United States, primarily through lower electricity bills. By 2020, the nation's overall energy bill will be reduced by more than $100 billion a year. Even factoring in the cost of the incremental investments in energy efficiency and cogeneration, the net savings to the U.S. economy in 2020 will exceed $80 billion a year. The *PowerSwitch!* scenario would significantly improve the overall reliability of the electric grid through the increased use of on-site cogeneration. It would also enhance the standing of the United States as a supplier of innovative and environmentally superior technologies and practices and thus stimulate the creation of high quality jobs in the process.

## 2 Introduction

The burning of fossil fuels—oil, gas and coal—emits carbon dioxide ($CO_2$) into the atmosphere where it builds up, blankets the earth and traps heat, causing global warming. The earth's atmosphere now contains more $CO_2$ than it has at any time during the last several hundred millennia—leading to impacts on coral reefs, arctic ice and other important habitats around the globe. What further changes will occur over the coming decades depends on how society chooses to respond to the threat of a dangerously disrupted climate. A concerted global effort to shift to energy-efficient technologies and carbon-free sources of energy could keep future climate change to relatively modest levels. If, on the other hand, nations continue to emit unlimited quantities of $CO_2$ emissions, climate change could ultimately be catastrophic.

Fortunately, there are a variety of effective technologies and policies available to meet the challenge of climate protection. In this report, we focus on implementing these solutions in the United States, which emits more than one-fourth of global $CO_2$. As a nation, the United States has both the responsibility and the capability to take the lead in climate protection and Americans can directly benefit from actions taken. To date, however, U.S. energy and climate strategies have not provided this leadership as they lack any binding obligations to reduce heat-trapping $CO_2$ emissions. We can and must do better.

This report presents a study of policies and measures through which the U.S. electricity sector could dramatically reduce its heat-trapping gas emissions over the next two decades, while spurring technological innovation and reducing pollution. Many of these policies were contained in bills before the 107th Congress, but none have yet been enacted into law. The study is consistent with many "bottom-up" technology studies that have shown that the nation can reduce its heat-trapping gas emissions and its energy bill simultaneously by expanding our use of energy efficiency and renewable energy resources.

### *The Risk of Climate Change*

Global emissions of $CO_2$ have steadily risen since the dawn of the industrial age and now amount to about 24 billion tons of $CO_2$ released annually from fossil fuel combustion and 4 billion tons annually from land-use changes (mainly burning and decomposition of forest biomass). Without concerted efforts to curb emissions, atmospheric $CO_2$ levels will be driven inexorably higher as a growing global population pursues the conventional approach to economic development based on energy derived from fossil fuels.

While it is impossible to accurately predict how much $CO_2$ humans will emit in the future, modeling allows us to explore various possible scenarios. In a business-as-usual scenario, annual emissions would approximately triple by the end of the century, while the atmospheric concentration of $CO_2$ would increase to three times pre-industrial levels, according to Intergovernmental Panel on Climate Change (IPCC), the international scientific body established to assess scientific, technical and socio- economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation (IPCC WGI 2001). The climatic impacts of these rising emissions could be dramatic.

Across a range of scenarios explored by the IPCC, global average temperatures are calculated to rise between 3 to 10 degrees Fahrenheit (1.5 to 6 degrees Celsius), with even greater increases in some regions (IPCC WGI 2001). There is likely to be severe consequences if world leaders fail to implement solutions in time to avoid high concentrations of $CO_2$. Sea level could rise between 3.5 to 35 inches (9 to 88 centimeters) (IPCC WGI 2001), with harsh implications for coastal and island ecosystems and their human communities. A sea level rise of 17 inches would inundate the communities of hundreds of millions of coastal inhabitants in the United States and abroad. Climate disruption would also likely entail more intense storms, floods and droughts.

These changes may occur very rapidly, rendering delayed attempts to mitigate climate change more hurried, more costly, less effective, or too late. Therefore, early and sustained action, across many fronts, is needed to reduce the risk from climate change by affecting the necessary technological, institutional and economic transitions to protect global climate and the ecological and social systems that depend on climate stability.

*Protecting the Climate*

Human activities have already released carbon dioxide that will remain in the atmosphere for many decades. This carbon dioxide has changed the climate and will continue to do so as long as it remains in the atmosphere. However, the degree of climate change to which we are already committed pales in comparison to the disruption that will result if we continue to recklessly emit more $CO_2$.

A responsible strategy to curb emissions would limit overall global warming to less than 2 degrees Celsius above pre-industrial levels by the end of the 21$^{st}$ century. This is about 1.4 degrees Celsius increment over the ~ 0.6 degrees C that has already occurred over the 20$^{th}$ century. Even within this temperature limit, it is far better if change happens slowly, to allow species and habitats to adapt. To achieve this goal, $CO_2$ concentrations would have to be stabilized at approximately 450 parts per million (ppm), or 60 percent above pre-industrial concentrations. The IPCC shows that stabilization at 450 ppm would result in an increment ranging around 1.8 degrees Celsius over this century. A more ambitious stabilization target might well be warranted, since this rate of change (averaging about 0.15 degrees Celsius per decade over this century) might not be as gradual as the 0.1 C per decade that could be needed to allow many ecosystems to adapt (Rijsberman and Swart 1990). Nonetheless the 450 ppm goal is an illustration of what might be environmentally acceptable and what could be achieved with a concerted effort by all of the nations of the world.

## 3 Technologies

A diverse set of clean energy technologies is available to greatly reduce emissions of $CO_2$ associated with power generation. These include technologies that increase the efficiency of electricity generation (such as cogeneration), technologies that reduce demand from consumers and business and renewable energy technologies that can supplant current and future generation. With the help of their customers as well as federal and state governments, electric utilities can begin the transition to a zero-carbon power sector by acting now to adjust their investment plans to favor clean energy options and increasing support for programs that reduce consumer demand for electricity. There are many market barriers to greater use of even cost-effective efficiency and cogeneration technologies, including the relatively high hurdle rate businesses and consumers impose on energy-saving investments. That is why dramatically expanded deployment of these technologies will require the kind of portfolio of policies modeled in the

*PowerSwitch! Case*. The following discussion covers a number of the existing clean energy options.

### 3.1 Energy Efficiency – Demand Side

*Energy Efficiency for Buildings*

Buildings are major consumers of electricity. Measures aimed at increasing energy efficiency can reduce the electricity consumption needed for heating, cooling, lighting and ventilation.

The ENERGY STAR® for Buildings program features a set of procedures and improvements that can reduce energy consumption by 30 percent in existing buildings, with average internal rates of return of 22 percent—in addition to gains in productivity and worker health (Romm 1999). These improvements include lighting retrofits, building equipment optimization and improvements to the building envelope, fan systems and heating and cooling plant equipment. Many of these steps can be adapted to improve the energy efficiency of a home as well.

Energy-efficient lighting is among the fastest and most cost-effective ways to improve the energy efficiency of a building. Lighting consumes 30 percent to 40 percent of the electricity of a commercial building and another 10 percent of the electricity is needed as cooling to offset the heat from the lights. For buildings that have not had lighting upgrades in the past five years, lighting costs can be cut 50 percent to 75 percent with a payback period of one to three years.

Building equipment may be optimized by the use of an energy management control system. These systems save energy while providing improved comfort to the occupants in terms of better temperature, humidity and lighting control. They also help improve indoor air quality, creating a healthier and more comfortable work environment. Building envelope improvements can help keep the cooling demand low in the summer, when electricity demand peaks in most parts of the country. Improving the energy efficiency of the windows, walls and roof can reduce the summer cooling load as well as the winter heating load.

In many cases, existing fan systems are larger than required; replacing them with smaller systems can increase energy efficiency. Fan systems that operate at a range of speeds can employ a variable speed drive to increase efficiency. If the heating and cooling load has been substantially reduced by other improvements, the heating, cooling and ventilation system can be replaced with a smaller system. If the existing chiller is old, then newer models with higher efficiency are likely to be available.

Absorption chillers use heat rather than mechanical energy to provide cooling. Absorption chillers have a high initial cost, but when the heat is produced as a byproduct of electrical generation, the fuel for the system is basically free. This trigeneration—on-site electricity generation with the waste heat used for heating in the winter and cooling in the summer—improves the economics and efficiency of the overall heating, cooling and power system.

*Energy Efficiency for Industrial Applications*

Most factories can cut energy consumption 25 percent or more with good payback through a combination of energy-saving strategies. The primary opportunity to reduce electricity demand in the industrial sector is to improve motor efficiency. Motors convert electrical energy to mechanical energy, powering fans, pumps, elevators, escalators, conveyor belts and industrial machines; they consume nearly 75 percent of the electricity used in industrial applications.

Opportunities for efficiency improvements are significant (Romm 1999). Motors are frequently oversized and they lose efficiency when operating at loads below their rated capacity. Reducing motor size can reduce energy costs by one-third with a payback period of eighteen months. The cost of energy to power a motor is considerably greater than the capital cost of the motor itself; typical motors use four to five times their cost in electricity each year. High-efficiency motors can reduce energy use by one-quarter to one-half. Potential improvements include re-sizing motors to meet demand and replacing inefficient motors with premium high-efficiency motors. Another key energy-saving strategy is installing variable speed drives (VSDs) on pump and fan motors that have variable loads. Computer-controlled VSDs can often significantly improve control of manufacturing processes, thereby boosting productivity. Compressed air systems—widely used for cleaning, running machine tools, running looms, mixing and moving product around on conveyor belts—can also be made 25 percent to 50 percent more efficient, with much of the savings coming just from fixing leaks.

*Industries of the Future*

For the energy-intensive process industries, technology roadmaps for increased efficiency have been developed through the U.S. Department of Energy's (DOE) *Industries of the Future* program. These include the chemicals, petroleum, glass, forest products, aluminum, steel and metal casting industries. The program sets targets for the different industries and works with industry partners to improve energy efficiency. For example, the aluminum industry uses about 15 kWh of electricity for every kg of aluminum produced. According to DOE's Office of Industrial Technologies, this industry consumed 65 billion kWh in 1999 (www.oit.doe.gov/aluminum). This is more than the combined generation of wind, woody biomass and geothermal energy. The *Industries of the Future* program seeks to reduce energy intensity by 25 percent or more. The DOE is working collaboratively with industry to develop dozens of electricity-saving technologies including revolutionary smelting technologies that could reduce the aluminum industry's electricity use by 25 percent or more, improve catalysts for the chemical industry, advance petroleum refining technologies and so on.

### 3.2 Energy Efficiency – Power Sector

Fossil fuel plants, especially coal plants are, on average, relatively inefficient, converting only about one third of the energy in the fossil fuel into electricity. The waste heat generated by that combustion is thrown away and then several percent of the energy is lost transmitting the electricity from the power plant to the factory or building. The total energy "wasted" by U.S. electric power generators equals all of the energy that Japan uses for all purposes: buildings, industry and transportation. To provide heat, hot water and steam, more fossil fuel is then burned in our buildings and factories. The average building boiler converts only two-thirds of the fossil fuel to useful heat or steam.

A great deal of energy and pollution can be saved by generating electricity and capturing the waste heat in a cogeneration or combined heat and power (CHP) system. Overall system efficiencies can exceed 80 percent. When the cogeneration system uses natural gas or biomass (replacing electricity or steam generated from coal or oil), further environmental benefits result.

Natural gas generates less $CO_2$ and other pollutants per unit of energy produced than either coal or oil. Biomass (discussed below) is a renewable fuel source with zero net emissions. From the point of view of $CO_2$ emissions, then, cogeneration has two benefits: the system is more efficient and it can use a cleaner fuel.

A variety of technologies can be used for combined heat and power (CHP), including traditional natural gas turbines, newer (and smaller) microturbines, reciprocating engines, steam turbines and fuel cells. A good source of information on these technologies is EPA's Combined Heat and Power Partnership (www.epa.gov/chp/chp_tools.htm).

The combined cycle gas turbine (CCGT) is the most efficient technology currently used for central-station power generation, with delivered efficiencies exceeding 50 percent. The CCGT combines a gas turbine with a steam turbine driven by waste heat from the gas turbine; waste heat from the steam turbine may be recovered as well.

Fuel cells hold great promise for generating electricity (and heat) very efficiently, cleanly and cost-effectively. Fuel cells convert chemical energy, typically from hydrogen, directly to electrical energy with water vapor as the only emission. In the near future, fuel cells coupled with gas turbines may generate electricity with delivered efficiencies approaching 70 percent. For the purposes of this study, we do not anticipate significant generation of power by fuel cells by 2020.

*Back-pressure steam turbines*

One decades-old technology deserves special mention because it is greatly underutilized and highly efficient in many applications: back-pressure steam turbines. In a steam turbine, energy is transferred from a steam boiler to the turbine through high-pressure steam that in turn powers the turbine and generator. Where a backpressure turbine is used, the steam exits the turbine at a design pressure suitable for process loads. This combined heat and power approach can be applied to every existing steam campus in the country, including industrial, commercial, medical and university complexes.

From the point of view of cost and environmental performance, a backpressure turbine is able to convert natural gas (or other boiler fuels) into electricity with an efficiency exceeding 80 percent. So applications where a backpressure turbine can be employed offer the opportunity to generate electricity with very low fuel cost and very low $CO_2$ emissions. One reason they are not more widely used is that the generation is on-site and thus reduces the load served by the monopoly utility. This has led the utilities to use interconnection rules, backup power charges and delays to frustrate installation of these devices. In spite of the problems, there are over 100,000 backpressure turbines operating worldwide. The potential deployment is in the millions and could generate 15 percent to 20 percent of the world's power.

### 3.3 Renewable Energy Technologies

*Wind energy*

Wind and solar energy were the two fastest growing forms of power in the 1990s in terms of annual percentage growth. Wind turbines convert the kinetic energy of the wind into mechanical power. This mechanical power can be used for specific tasks such as grinding grain or pumping water; windmills have been used for these tasks for hundreds of years. More recently, wind turbines have been developed to convert this mechanical power into electricity. Wind turbines are often grouped together into "farms" to generate bulk electrical power. Electricity from these turbines is fed into the local utility grid and distributed to customers.

The United States has exceptional wind resources. Areas such as the East Coast, the Appalachian Mountain chain, the Great Plains and the Pacific Northwest have wind resources that are suitable for the generation of power. North Dakota, alone, has enough energy from high wind resources to supply 36 percent of the electricity of the lower 48 states. However, this surfeit of wind resource must be tempered by the fact that much of the available wind is not located near the consumer or the existing transmission and distribution networks. Therefore, if wind were to become a significant portion of the generation mix, it would require additional investments in transmission infrastructure and some upgrading of distribution.

Over the past 15 years, significant aerodynamic improvements in blade design have brought down the cost of electricity from wind power by 10 percent per year. New, utility-scale wind projects are being built all around the United States today and delivering electricity at prices as low as 4 cents per kilowatt-hour in the best wind sites. Aggregated installed wind in the United States is roughly 2,000 MW. The next generation wind turbine is projected to bring costs down to 3 cents per kilowatt-hour or less over the next several years (including the wind production tax credit). Since wind is an intermittent electricity generator and does not provide power on an "as needed" basis, it loses some value on a per kilowatt-hour basis, compared to traditional electric generation that can provide baseload power. On the other hand, wind provides benefits in terms of reduced emissions and elimination of fuel risk that can more than make up for this lost value.

*Biomass energy*

Organic matter known as biomass can be used for the production of electric power, heat, vehicle fuel and chemicals. Biomass includes plant matter such as trees, grasses, agricultural crops or other biological material. The installed capacity of 7,000 MW of biomass electricity generation makes it the second-most utilized renewable power generation resource in the U.S. (after hydropower). The 37 billion kWh of electricity produced each year from wood and wood waste biomass is nearly as much as the entire state of Colorado uses annually (EIA 2002). Electricity generation uses around 60 million tons of biomass per year.

Several technologies exist to convert biomass to electricity (or heat). The majority of biomass electricity is generated using a steam cycle: biomass material is converted to steam in a boiler; the steam then turns a turbine that is connected to a generator. Roughly 75 percent of the energy emerges as thermal energy that can be used for heating and process, providing siting of the power plant is near a steam campus. Biomass can also be co-fired with coal to produce power from an existing power plant. This is the most economical near-term option for introducing new biomass power generation and produces lower air pollutant emissions than coal alone. Solid biomass can be converted into a fuel gas through gasification or by bacteria through anaerobic digestion. The fuel gas can then be used in a piston-driven engine, high-efficiency gas turbine generator or a fuel cell. Biomass gas electricity produces even fewer emissions than solid biomass electricity.

The cost of biomass electricity depends on the type of technology used, the size of the power plant and the cost of the biomass fuel supply. In a direct-fired biomass power plant, current generation costs are about 9¢/kWh. Advanced technologies such as gasification-based systems could generate power for as little as 5¢/kWh. For cofiring applications, biomass fuel can cost less than coal when low cost biomass fuels are used; modifications to the coal plant may add some expense but can have payback periods of 2-3 years. Biomass-fired CHP can be cheaper than the best new central generation fired with coal or gas. Presently unused quantities of economically available biomass could supply about 7,500 MW of new biomass electricity in the United States, doubling the existing U.S. biomass capacity. Unused resources include urban tree trimmings, waste wood and crop waste such as rice hulls and corn husks.

*Solar Photovoltaics*

Photovoltaic (or PV) systems convert light energy directly into electricity. PV systems power applications ranging from wristwatches to road signs to telecommunications equipment to homes and offices. Worldwide PV cell shipments rose by 36 percent to 530 MW, as Japanese manufacturers set the pace on expansion of solar cell manufacturing capacity. The United States became the fastest growing major PV market in 2002. The size of systems ranges from a few milliwatts for a calculator to a few megawatts for a utility power plant. The mid-day electricity costs of more than one-fifth of consumers are higher than the current cost of electricity from photovoltaics.

The United States has the best solar resource of any industrialized country. Harnessing this resource to produce electricity has been expensive, but costs have been dropping rapidly and interest is growing in these promising technologies. We expect PV to be a major source of carbon-dioxide-free power for the United States after 2020. For the purposes of this study, we do not anticipate significant generation of power by PV.

*Geothermal energy*

The earth's energy can be converted into heat and electricity using technologies such as geothermal heat pumps, direct-use applications and power plants.

Geothermal heat pumps can be used cost-effectively almost everywhere in the United States. In the continental United States, the upper 10 feet of Earth's surface maintains a nearly constant temperature between 50 degrees and 60 degrees Fahrenheit. Geothermal heat pumps take advantage of this constant temperature to heat and cool a building. They typically run piping a few hundred feet below the Earth's surface (or occasionally connect to a nearby body of water). Here, the temperature stays relatively constant throughout the year. Since the ground is warmer than the outside air in the winter, the geothermal system has to expend less energy than conventional systems to heat up a building. Similarly, since the ground is colder than the outside air during the summer, the geothermal system has to expend less energy than conventional systems to cool down a building.

Direct-use geothermal systems pipe hot water from the ground for domestic, agricultural and industrial applications. In the United States, most geothermal reservoirs are located in the western states, Alaska and Hawaii. In some locations, hot water near Earth's surface can be piped directly into facilities and used to heat buildings, grow plants in greenhouses, dehydrate onions and garlic, heat water for fish farming and pasteurize milk. District heating applications use networks of piped hot water to heat buildings in whole communities.

Power plants generate electricity from geothermal reservoirs. Wells drilled a mile or deeper into underground reservoirs tap steam and very hot water to drive turbines and produce electricity. Geothermal power generates about 14 million kWh per year, or about as much electricity as is used in the state of Maine.

The three technologies discussed above use only a tiny fraction of the total geothermal resource. Several miles everywhere beneath Earth's surface, hot, dry rock is heated by the molten magma directly below. Technology is being developed to drill into this rock, inject cold water down one well, circulate it through the hot, fractured rock and draw off the heated water from another well. If "hot dry rock" technology is developed at competitive costs, the resource base for geothermal power will expand significantly. Geothermal electricity production was about 14 billion kWh in 2000 and 2001 (EIA2002).

## 4 Policies

This study examines a broad set of national policies that would increase energy efficiency, accelerate the adoption of renewable energy technologies and shift to less carbon-intensive fossil fuels. The policies address major areas of energy use in the buildings, industrial and electric generation sectors. Analyses of the investment costs and energy savings of policies to promote energy efficiency and co-generation in the residential, commercial and industrial sectors were taken primarily from the American Council for an Energy Efficient Economy (1999; 2001 and 2002). Below we group these policies into the particular sector where they take effect and describe the key assumptions made concerning the technological impacts of the individual policies. Unless otherwise indicated, each of the policies is assumed to start in 2004.

As explained further in the methodology discussion in the next section, we adapted the Energy Information Administration's 2002 Reference Case Forecast from the Annual Energy Outlook (EIA 2001) to create a slightly revised *Base Case*. Our policies and assumptions build on those included in this *Base Case* forecast (i.e., we avoid taking credit for emissions reductions, costs, or savings already included in the EIA 2002 Reference Case). When taken together, the policies described in this section represent a *PowerSwitch!* scenario that the United States could pursue to achieve significant $CO_2$ reductions.

### 4.1 Policies in the Buildings and Industrial Sectors

The buildings sector (including both residential and commercial) accounts for about 10 percent of U.S. $CO_2$ emissions from direct (on-site) fuel combustion, while such direct emissions from the industrial sector account for another 20 percent. Adding in the so-called indirect emissions generated in the production of the electricity consumed by these sectors raises these levels to 35 percent for buildings and 30 percent for industry. We modeled reduction strategies that include new building codes, new appliance standards, tax incentives for the purchase of high efficiency products, a national public benefits fund, expanded research and development, voluntary agreements and support for combined heat and power. Our focus is more efficient electricity consumption, but these policies also generate savings in direct fuel combustion.

*New Appliance and Equipment Efficiency Standards*

Electricity efficiency standards have achieved remarkable results, beginning with the National Appliance Energy Conservation Act of 1987 and subsequently the various updates that were promulgated in early 2001 for washers, water heaters and central air conditioners. These standards have eliminated from the market the most inefficient models, while still giving consumers myriad products to choose from. Almost 8 percent of annual electricity usage will be saved in 2020 thanks to standards already enacted (Geller et al. 2001). Yet, a number of appliance efficiency standards have not satisfied legal updating requirements nor responded to technological advances. The U.S. Department of Energy (DOE) is far behind its legal obligation to periodically raise standards for some appliances to the "maximum level of energy efficiency that is technically feasible and economically justified."

We model upgrades to existing standards or new standards for several critical pieces of equipment: distribution transformers, commercial air conditioning systems, residential heating systems, commercial refrigerators, exit signs, traffic lights, torchiere lighting fixtures, ice makers and standby power consumption for consumer electronics. The study also models higher standards for residential central air conditioning and heat pumps than the Bush Administration put in place. These steps can be taken quickly, based on off-the-shelf, cost-effective technologies.

*Building codes*

In our analysis, all new residential and commercial buildings are built to a minimum level of energy efficiency that is cost-effective and technically feasible through the application of building energy codes. "Good practice" residential energy codes have been put in place by 32 states and "good practice" commercial energy codes have been put in place by 29 states (BCAP 1999). However, the Energy Policy Act of 1992 (EPAct) requires all states to adopt such a commercial building code.

We model that the DOE enforces the commercial building code requirement in EPAct and that states comply and that relevant states upgrade their residential energy code to either the 1995 or 1998 Model Energy Code. In addition, in our analysis the model energy codes are significantly strengthened in the coming years and that all states adopt mandatory codes that go beyond current "good practice" by 2010. We estimate that these policies would result in a 20 percent energy savings in heating and cooling in buildings in half of new homes and commercial buildings.

*Expand Federal Funding for R&D in Energy Efficient Technologies*

One of the most cost-effective federal investments has been R&D funding for energy efficiency technologies. The energy saved from some two dozen federal energy efficiency R&D efforts has been about $30 billion to date—over three times all federal spending for energy efficiency and renewable energy R&D in the 1990s (EERE 2000). These R&D efforts must be accelerated, since they address all of the energy problems created by our reliance on fossil fuel, such as climate change, environmental damage and dependence on oil from unstable regions.

Large opportunities remain for continued progress in lighting, electric motors, manufacturing processes, windows, building shells and heating and cooling systems, for example. Similarly, the ENERGY STAR® program of the U.S. Environmental Protection Agency, together with the DOE, has helped accelerate the use of more efficient products and buildings. Given this achievement, the ENERGY STAR® program should be expanded to other products (refrigerators, motors) and building sectors (hotels, retailers). We model that expanded R&D efforts in buildings and industry will lead to more energy-efficient products in the coming years.

*National Public Benefits Fund*

For decades, electric utilities have given incentives to their customers to use more efficient energy-using equipment, helped low-income families weatherize their homes, helped commercialize renewable power and supported research and development (R&D). Such efforts have achieved electricity bill savings for households and businesses that are about double the program costs (Nadel and Kushler 2000). Yet, even with the demonstrated success of such efforts, utilities have cut these "public benefit" investments recently, in part because of increased competition. To save these programs, over a dozen states have put in place public benefits funds supported by a small surcharge on all electricity delivered to consumers.

We analyze a national level public benefits fund (PBF) modeled after the one introduced by Sen. Jeffords (S. 1369) and Rep. Pallone (H. 2569) in the 106th Congress. This fund would place a surcharge of 0.2 cents per kilowatt-hour on all power sold, costing the typical residential consumer about $1 per month. The PBF would then match funds for states for approved public benefits expenditures. We model the fund distributing to programs aimed at improving lighting, air conditioning, motors and other cost-effective energy-saving technologies.

*Tax incentives*

A variety of proven energy-saving products have not achieved marketplace success. One reason is that conventional technologies get "locked-in"—achieving economies of scale, brand awareness and consumer familiarity, together with an existing supply and repair channel, that put alternatives at a disadvantage—even ones that could be economically viable with widespread usage and mass-production. Temporary tax incentives can help bring advanced alternatives into the market and, once they have a foot-hold, the incentives can be dropped.

We model such initial tax incentives for several products. In the case of commercial buildings with 50 percent or greater reduction in heating and cooling costs relative to applicable building codes, we modeled an incentive of $2.25 per square foot. In the case of consumer appliances, we modeled a tax incentive of $50 to $100 per unit. In the case of new homes that are 30 percent or more efficient than the Model Energy Code, we modeled an incentive of up to $2,000 per home.

For building equipment like efficient furnaces, fuel cell power systems, gas-fired heat pumps and electric heat pump water heaters, we analyzed a 20 percent investment tax credit. We introduce all of these incentives with a sunset clause, ending them in about five years, ensuring they do not become permanent subsidies. Versions of all of the tax incentives considered here have already been introduced into bills before the U.S. Senate and/or House of Representatives.

*Industrial Energy Efficiency and Pollution Reduction Targets*

Today's industrial facilities have significant unrealized potential to save energy cost-effectively (Romm 1999) and a few managers have begun to achieve that potential. For instance, Johnson & Johnson set a goal in 1995 of cutting energy costs 10 percent by 2000 by employing "best practices" in its nearly 100 U.S. facilities. Then, Johnson & Johnson pledged in 2000 to cut $CO_2$ emissions to 7 percent below 1990 levels by the year 2010, as part of the Climate Savers Program, an international program of WWF. In the United States, WWF partners with the CECS in managing Climate Savers. Companies as diverse as IBM, Nike, Polaroid, Alcoa, Kodak, Entergy, DuPont and Royal Dutch Shell also find it makes good business sense to commit to corporate-wide $CO_2$ reduction targets. These companies understand they are becoming better prepared for a future that increasingly puts a value on $CO_2$ reductions.

Both energy-intensive and non-energy intensive industries have large opportunities to cut energy use cost-effectively (Elliott 1994). For instance, one in-depth analysis of four dozen energy-saving technologies for the iron and steel industry determined that combined energy savings of 18 percent was cost-effective (Worrell, Martin and Price 1999). Moreover, many energy saving measures increase productivity, providing further economic benefits that we do not model here (Romm 1999). We model federal efforts to accelerate the use of energy-saving technologies and strategies by industry though technical and financial assistance and expanded R&D efforts.

*Support for Combined Heat and Power Generation*

The simultaneous generation of heat and power—which are normally produced separately, sometimes doubling total primary energy consumption—is called cogeneration or, combined heat and power (CHP). The value of this highly-efficient strategy has been widely demonstrated. Indeed, within the United States, states produce from zero percent to 33 percent of total power on-site, where waste heat can used productively (Casten & Collins 2002). This variance demonstrates that federal law and regulatory barriers are not the predominant impediment to CHP, but rather states that have encouraged CHP have had great success and those that effectively discourage it have locked in inefficient central generation without heat recovery.

Cogeneration today generates only 9 percent of all U.S. electricity, in part because of major barriers to greater use (Elliott and Spurr 1999; Casten 1998). Utility practices are often hostile to potential CHP operators, especially in the costs they charge for back-up power and for connecting to the grid. Environmental regulations fail to credit the greater overall efficiency of CHP systems, for example by assessing facility emissions on the basis of fuel input, rather than useful energy output. Furthermore, the locational value of CHP, at or near the user, avoids transmission and distribution (T&D) losses that can approach 10 percent and lessen need for new T&D, but is not recognized or made available to developers of CHP and on-site generation.

We model putting into place better environmental standards, a standard permitting process, consistent tax treatment and fair access to electricity consumers through the grid. These policies help the country realize much of the huge, untapped CHP potential, achieving 50 GW of new CHP capacity by 2010 and an additional 95 GW between 2011 and 2020. Cogenerated power reaches 14 percent of total electricity required in 2010 and 28 percent in 2020.

## 4.2 Policies in the Electric Generation Sector

The major goal of this study is to show how the United States can dramatically and cost-effectively reduce $CO_2$ emissions from the electric sector, which is responsible for more than one-third of all U.S. emissions of heat-trapping gases. We analyzed policies and measures in this sector that are aimed at overcoming existing market barriers to investments in pollution-reducing technologies. Two major policies were modeled: a Renewable Portfolio Standard and caps on pollutant emissions.

*Renewable Portfolio Standard*

A Renewable Portfolio Standard (RPS) speeds the introduction of renewable technologies into the electric sector. It establishes a minimum amount of renewable power as a fraction of total electricity generation. Each producer that sells electricity must meet this minimum either by generating that amount of renewable power in its mix or acquiring credits from producers that exceed the minimum. The market then finds the set of technologies and the geographic distribution of power plants that meet the target at the lowest cost through a trading system that awards credits to producers for generating renewable electricity and allows them to buy or sell these credits. More than a dozen states, including Arizona, California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Minnesota, Nevada, New Jersey, New Mexico, Pennsylvania, Texas and Wisconsin, already have RPSs and a bill to establish a national RPS was passed by the Senate in the 107th Congress (S. 517). Governor Pataki recently announced that New York will develop an RPS that would require 25 percent of electricity to come from renewable energy resources within ten years. This amount may include hydropower, but the terms of the RPS have not yet been established.

The Renewable Portfolio Standard will stimulate the design of low-cost renewable systems. By speeding the deployment of renewable technologies, the RPS would also speed the learning and economies of scale that permit renewable technologies to become more and more competitive with conventional generation technologies. This is especially critical as achieving climate stabilization will necessitate far more renewable energy than we can deploy in the next two decades. Adding renewable energy generation capacity can also reduce demand for gas generation thereby reducing gas prices. A 2001 study by the Energy Information Agency shows that a RPS of 20% by 2020 would cause reductions in gas price leading to no net increase in energy bills nationwide (EIA 2001).

In this study, we have applied an RPS that starts at 4 percent of total electricity sales in 2004, increasing to 10 percent in 2010 and 20 percent in 2020. Wind, solar, geothermal, biomass (including co-firing of biomass at existing coal plants) and landfill gas are eligible renewable sources of electricity, but environmental concerns exclude municipal solid waste (because of toxic emissions from waste-burning plants) and large-scale hydro (which also does not need to be treated as an emerging energy technology as it already supplies nearly 10 percent of the nation's electricity supply).

*Carbon Dioxide Cap-And-Trade Permit System*

This study models a cap-and-trade system for carbon dioxide in the electric sector, with a cap at the equivalent of 25 percent below 1990 levels by 2010 and 50 percent below 1990 levels by 2020. Permits for emissions under the cap are distributed through an open auction and the resulting revenues can be returned to households (for example, through a tax reduction or as a rebate back to households, impacted communities and businesses). Recent studies have found that an auction is the most economically efficient way to distribute permits, achieving emissions caps at lower cost than allocations based on grandfathering allowances or equal per-kWh allowances (Burtraw et al. 2001). An auction is also the system most straightforwardly expandable to cover other emitting sectors. The caps in this *PowerSwitch! Case* were found to have a market-clearing price of $15/ton.

The $CO_2$ cap-and-trade system can help to accelerate replacement of old power plants with new ones, to replace more polluting fossil-fuel-based generation with cleaner and renewable forms of power generation and to replace low-efficiency plants with high-efficiency ones. For example, combined cycle gas turbine plants provide far higher electrical efficiencies than coal-fired power plants and they use a low-carbon fuel. This technology produces less than half the $CO_2$ emissions per kWh of a coal plant.

*Four Pollutant Reduction*

Urban air pollution and acid rain remain significant problems in this country. Even with the gains brought about by the Clean Air Act and its amendments, recent studies have confirmed that $SO_2$ and $NO_x$ continue to harm lake and forest ecosystems, decrease agricultural productivity and affect public health through its damaging affects on urban air quality (Clean Air Task Force, 2000). Mercury emissions are likewise a significant health problem. Most of the mercury in the atmosphere is elemental mercury vapor, which circulates in the atmosphere for up to a year and hence can be widely dispersed and transported thousands of miles from likely sources of emission. Fortunately, industrial demand for mercury has declined by about 75 percent between l988 and l996. In addition, the U.S. EPA finalized emission limits for municipal waste combustors and medical waste incinerators, resulting in emissions reductions in 2000 of approximately 90 percent from 1995 levels. Consequently, the largest remaining identified sources of mercury emissions are coal-fired utility boilers (EPA Report to Congress 1998).

Using a cap for SOx, NOx and mercury along with the $CO_2$ cap, this scenario reduces multiple emissions from power plants, in a manner similar to that adopted in the Four Pollutant Bill that is before the Senate (S. 366) in the $108^{th}$ Congress. The reductions in these four pollutants are as deep as those imposed in the Four Pollutant bills and are achieved within a comparable time frame. We are specifically modeling:

- cap sulfur dioxide ($SO_2$) emissions at 2.87 million tons in 2010 and 2.27 million tons in 2016 (emissions are 11 million tons today)

- cap nitrogen oxides ($NO_x$) emitted by power plants at 1.548 million tons in 2008 (emissions are 5 million tons today)
- cap mercury emissions from power plants at 5 tons in 2008 (emissions are 48 tons today)

While not specifically targeted by the trading programs, it is likely that some older coal plants will be retired as the large amount of allowances required to keep them running and in regulatory compliance would be very expensive. Operators of the 850 old "grandfathered" coal units built before the Clean Air Act of 1970 emit three to five times more pollution per unit of power generated than newer coal power plants. When the Clean Air Act was adopted, it was expected that these dirty power plants would eventually be retired. However, utilities are continuing to operate these plants beyond their design life and have in fact increased their output over the last decade. By subjecting these old plants to the same requirements as newer facilities, as has been done or is being considered in several states including Texas and Massachusetts, operators would be obliged to modernize the old plants or to replace them with cleaner electric generation alternatives.

This highlights a benefit of four-pollutant strategies versus three-pollutant strategies that omit $CO_2$ caps. Since action to limit $CO_2$ emissions is increasingly inevitable given the growing scientific consensus and the commitment by the rest of the industrial world to take action now, putting off action on $CO_2$ until after action is taken on the three pollutants will only serve to increase costs and encourage inefficient use of capital. Indeed, many measures to reduce one or more of the three pollutants, such as scrubbers, can actually increase $CO_2$ emissions. The best strategy for the nation is to direct utility owners to plan to make all of the inevitable reductions together, thereby discouraging utilization of technologies that only deal with one or two of the pollutants and maximizing the synergies of accelerating the transition to clean power technologies.

## 5 Methods and Assumptions

The modeling for this study was based primarily on the National Energy Modeling System (NEMS) of the U.S. Department of Energy, Energy Information Administration (DOE/EIA) (EIA 2001). The NEMS model version, data and assumptions employed in this study were those of EIA's *Annual Energy Outlook* (EIA 2001), which also formed the basis for the *Base Case*. We refined the NEMS model with advice from EIA, based on their ongoing model improvements and drawing on expert advice from colleagues at the American Council for an Energy Efficient Economy (ACEEE) and the Union of Concerned Scientists, the National Laboratories and elsewhere. For a more detailed discussion of methodology and assumptions, see Appendix Two at http://www.worldwildlife.org/PowerSwitch.

Analyses of the costs and demand impacts of policies to promote energy efficiency and cogeneration in the residential, commercial and industrial sectors were taken from ACEEE (ACEEE 1999; ACEEE 2001) with adjustments to account for the delayed starting point of the policies in this analysis (see Appendix 2 for energy reductions associated with each policy). These studies have been widely reviewed and achieve similar energy reductions at similar costs as other bottom-up analyses focused on strong policies for heat-trapping gas emission reductions. Many options exist for increased energy efficiency and cogeneration and for types of programs to achieve these energy reductions—and future technologies and policies could provide even more opportunities. Though uncertainties of energy use and costs exist in both the *Base Case* and *PowerSwitch!* cases, the results of this study represent a robust estimate of the impacts of such policies—given political will to address climate change and absent large unforeseen changes in underlying conditions.

For this study, we used information from the ACEEE studies on demand sector policies to lower the fuel and electricity demand within NEMS. We also changed the parameters in NEMS to simulate the renewable portfolio standard, the $CO_2$ cap and trade program and the NOx, $SO_2$ and mercury cap and trade programs. We ran NEMS to determine the new mix of electric capacity and generation (based on changes in both electricity demand and the electricity sector policies). The NEMS model takes account of the interactions between electricity supply and demand (aggregated residential, commercial and industrial), taking account of the mix of competitive and still regulated pricing in the United States. It accounts for the feedback effects between electricity market and power plant construction decisions, as well as the links between fuel demands, supplies and prices.

Our use of NEMS for this project focused on the Electricity Market Module (EMM), complemented by the Oil and Gas Supply Module (OGSM). The EMM starts with the detailed fleet of existing power plants in the thirteen electric sector regions of the U.S. and also represents power imports from neighboring Canadian regions. It makes dispatch, construction, interregional purchase and retirement decisions based upon the regional electricity demands and the cost and performance characteristics of existing and new electric supply options, adhering to national pollutant caps and any state-level RPS requirements. It also takes account of cost reductions of new power plants with increased units in operation (learning and scale economies). The OGSM tracks changes in prices of natural gas and petroleum fuels based on changes in their demand. The electric generation, fuel and emissions savings plus electricity and natural gas price changes from these policies were obtained from NEMS, to take account of all of the interactive and feedback effects described above caused by the demand and electric sector policies together.

Details on the modifications that we made to the *Base Case* and the estimates of electricity reductions from the demand and cogeneration policies are included in an expansion of Appendix Two that can be found at http://www.worldwildlife.org/PowerSwitch. Further information on NEMS is available from the Energy Information Administration's website, http://www.eia.doe.gov/bookshelf/docs.html.

## 6 Results

The results of this analysis are very promising. They show that with a set of innovative and ambitious policies the U.S. electricity sector can cut its $CO_2$ emissions by more than half (from present levels) by 2020. Under this scenario, electricity prices rise slightly, but due to more efficient use of electricity, electricity bills drop substantially. The gross annual savings in energy bills to businesses and households averages over $10 billion per year from 2004 to 2020. The net savings of the *PowerSwitch!* scenario, including the costs for more energy-efficient equipment and additional cogeneration (plus transfers of revenue from the $CO_2$ cap and trade program back to the consumers), average $20 billion per year from 2004 to 2020 and exceed $80 billion in 2020.

In the *PowerSwitch!* scenario, the growing demand for electricity services by businesses and households is met with substantially reduced purchased electricity and thus less central station power generation, than in the *Base Case*—because of the greater use of energy efficiency and cogeneration. The *PowerSwitch!* scenario shows only a small increase in electricity generation from current levels, rather than the steady increase that would otherwise occur, yet consumers and businesses receive the same or better energy services in 2020 than in the business-as-usual case, even while the U.S. population is expected to rise some 20 percent and industrial output increase by 76 percent. This reduces the need for new infrastructure, power plants, fuel combustion and emissions. Indeed, with onsite cogeneration and greater fuel diversity, the power system is much more reliable and must less vulnerable to external disruption. The electricity sector evolves to be considerably less carbon-intensive, with fossil fuels accounting for under 60 percent of all electricity generation by 2020.

Our analysis compared three scenarios: the *PowerSwitch!* suite of policies, a business-as-usual *Base Case* and business as usual with caps on emissions of nitrogen oxides, sulfur dioxide and mercury but not on carbon dioxide. In this *Base Case with Three Caps*, constraints on those three pollutants produced modest reductions in $CO_2$ emissions. In this scenario, while $CO_2$ emissions in 2020 were 5.6 percent less than in the *Base Case,* they increased 27 percent over 2000 levels.

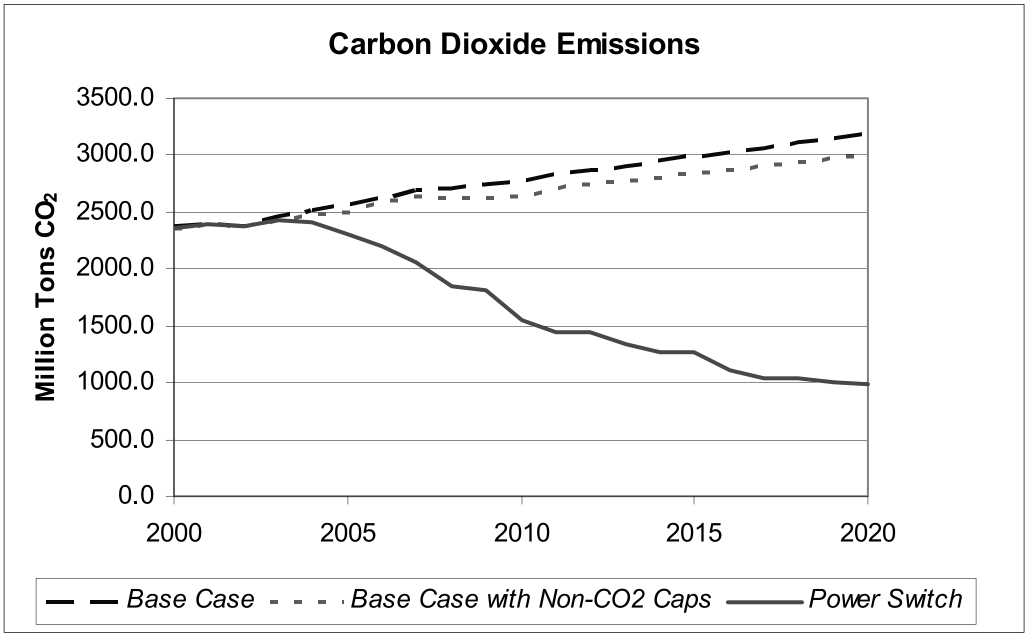
Table 6.1 provides summary results on overall energy, $CO_2$ and economic impacts for the *Base Case* and *PowerSwitch! Case* for 2020. The portfolio of carbon-dioxide-reducing policies and measures composed for this *PowerSwitch!* scenario brings the United States a long way toward achieving zero-carbon power generation by mid-century.

| *Table 6.1 Summary of results* | | | |
|---|---|---|---|
| | **2000** | **2020** | **2020** |
| | ***Base Case*** | ***Base Case*** | ***PowerSwitch!*** |
| **Electricity Generation** (Billion kWh) | | | |
| Central station | 3504 | 4994 | 2811 |
| Cogeneration | 307 | 446 | 1111 |
| Total | 3811 | 5440 | 3921 |
| **Non-Hydro Renewables** (BkWh) | 63 | 149 | 768 |
| **Net $CO_2$ Emissions** (megatons $CO_2$/yr)* | 2367 | 3193 | 979 |
| **Savings** | | | |
| Levelized annual (economy-wide 2004-2020): | $20 billion per year (2000$) | | |

*$CO_2$ emissions for the Base Case are from all "Central Station" electric power generators, but exclude emissions from "Cogeneration" following the reporting method used in NEMS. Thus, in Table 6.1 we ascribe no emissions to electricity from on-site Cogeneration in the Base Case, which increases from 307 to 446 Billion kWh between 2000 and 2020. Assumptions about the allocation of fuel use between thermal and electricity outputs would be required to estimate emissions from Base Case Cogeneration, for which accurate information is not readily available. Therefore, Table 6.1 only provides the *increase* in emissions from additional on-site cogeneration (versus new boilers), above and beyond the Base Case level of Cogeneration, which result from the policies described in this report.

The reductions in electricity-related carbon dioxide emissions, seen in Figure 6.0, are even more dramatic than the reductions in electricity consumption, because of the shift toward renewable energy and lower-carbon fuels (i.e., from coal to gas) and to more efficient power generation. In the *Base Case*, electricity-related $CO_2$ emissions are projected to rise by more than 30 percent from 2000 to 2020. In the *PowerSwitch! Case*, the United States promptly begins to reduce electricity-related $CO_2$ emissions and by 2020, emissions are about 60 percent below 2000 levels.

**Figure 6.0 Modeled Carbon Dioxide Emissions**




* The information in this figure is taken from Table 6.1.

## 6.1 Electricity Generation

Figure 6.1a below illustrates electricity generation through 2020 in the *Base Case* scenario. This case shows a significant increase of more than 40 percent in electricity generation from 2000 to 2020. The mix of generation sources remains strikingly similar over the twenty-year period, with gas-fired power showing the only significant increase (more than 200 percent) over the time period. Renewable electric generation still plays only a very minor role in the mix.

The *PowerSwitch!* policies we modeled in the buildings and industrial sectors, however, lead to major reductions in the total amount of electricity required from the nation's power stations in the next two decades compared with business as usual. This impact is illustrated in Figure 6.1b and shows that energy efficiency measures entirely displace growth in electricity demand after 2005. Relative to 2000's level, electricity demand increases 6 percent by 2010 and then drops for a net 3 percent increase by 2020.

In addition to this reduced demand for electricity, the mix of fuels used to generate electricity changes dramatically, as shown in Figure 6.1b. The electric sector policies shift the generation mix away from a heavy reliance on coal and avoid the rapid build-up of natural gas generation, by relying much more on renewable energy and, especially, cogeneration. Cogeneration grows from roughly 300 TWh today to 1100 TWh in 2020, whereas in the *Base Case* cogeneration increases modestly to over 440 TWh in 2020. Non-hydro renewable energy consumption in 2020 is over five times as great under the *PowerSwitch! Case* as it is in the *Base Case*.

Figure 6.1a

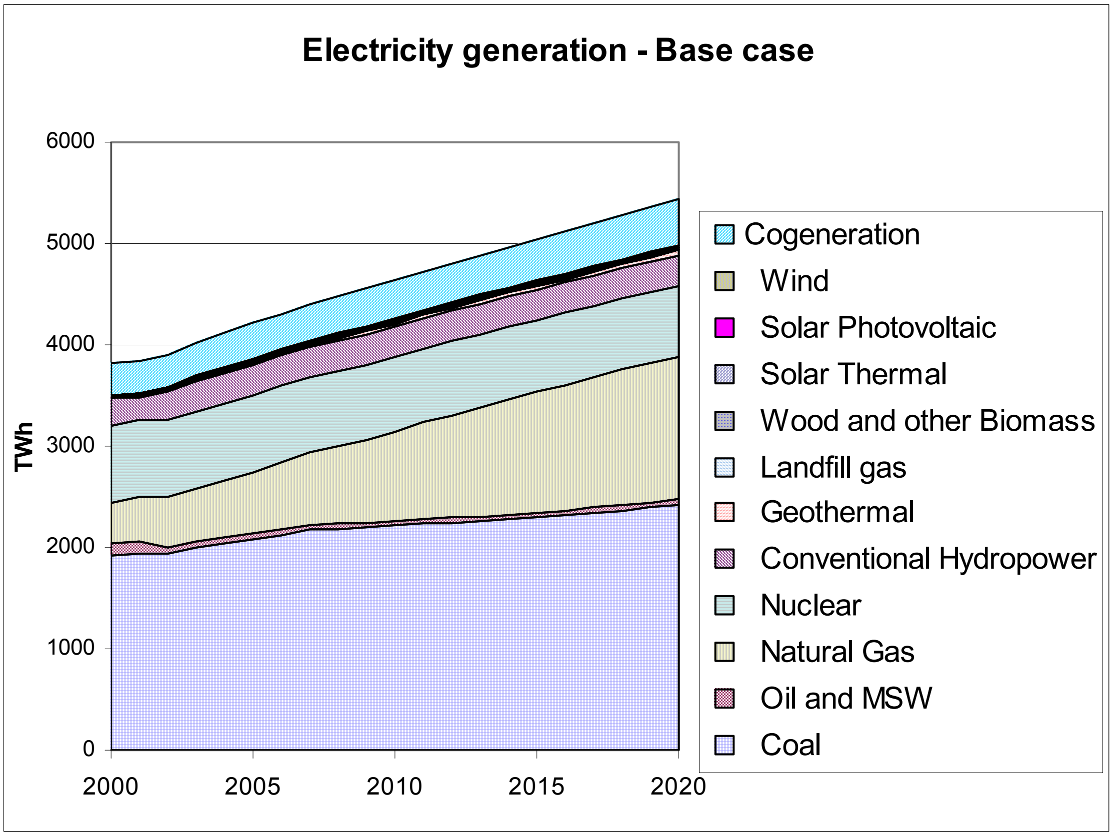
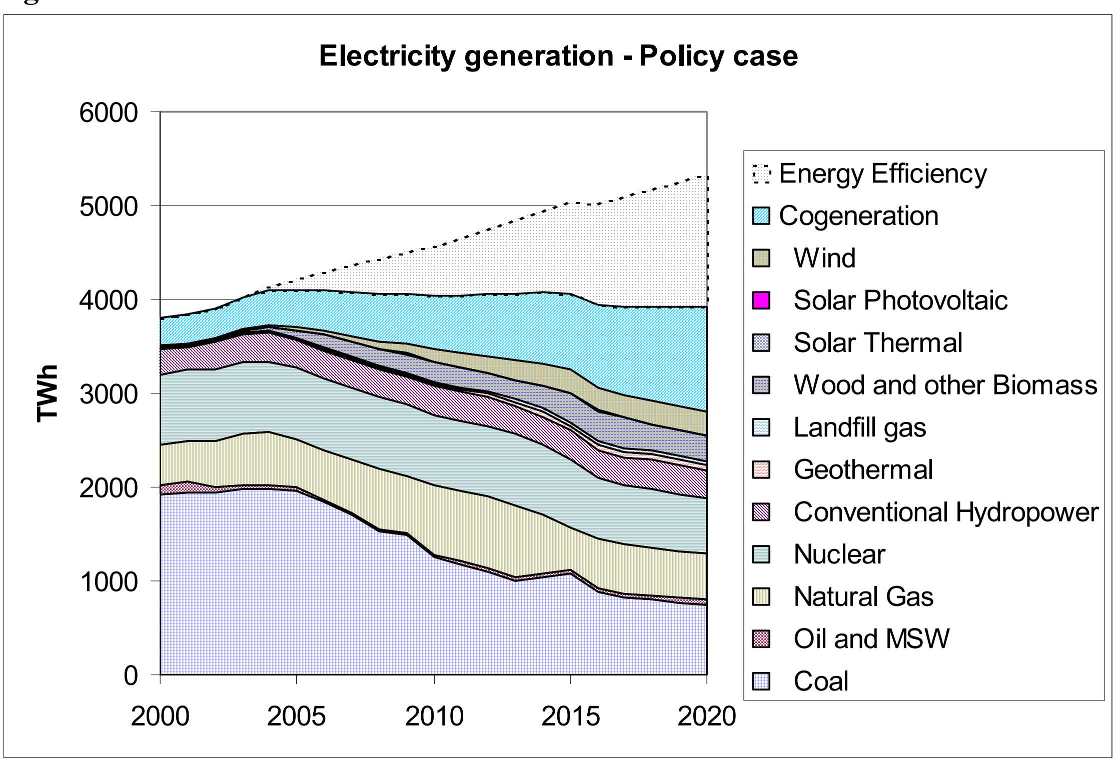



Figure 6.1b



## 6.2 Economic Impacts

The *PowerSwitch!* portfolio of policies and measures considered here is a very robust package that sets the nation on a path to achieving zero-carbon electricity by mid-century. Despite the ambitiousness of this package and the impressive $CO_2$ impacts, it would bring net economic *benefits* to the country. National savings in energy bills would exceed the net incremental investments in more efficient technologies and expenditures for low-carbon fuels. The overall effect is an annual savings in electricity bills to households and businesses that averages over $10 billion per year from 2004 to 2020. Total net annual savings to the economy during that time average $20 billion per year. Table 6.2 presents these results.

**Table 6.2 Savings from *PowerSwitch!* policies**

| | Annual | Annualized Savings | Cumulative Present Value |
|---|---|---|---|
| | 2020 | 2004-2020 | 2004-2020 |
| (billion 2000$) | | | |
| Energy bill savings | $121 | $11 | $126 |
| Revenue transfers from cap and trade programs | $36 | $31 | $350 |
| Incremental investments in efficiency and CHP | -$70 | -$22 | -$248 |
| Total | $86 | $20 | $229 |

Note: Annualized and cumulative present value calculations use 5 percent discount rate

*Energy bill savings* are the reductions in expenditures on energy by the residential, commercial and industrial sectors. This value includes the impacts of both reductions in purchased energy (electricity, natural gas, oil and coal), due to the policies to increase energy efficiency and CHP levels and changes in energy prices. The differences in energy prices between the *Base Case* and the *PowerSwitch! Case* reflect a number of aspects that can lead to either increased or decreased prices. One aspect of the electricity price change is the impact of changes in capacity and generation levels and mix—the reduced electricity demand will lead to lower investment in new capacity and lower total fuel costs for generation but the RPS will lead to increased purchases of renewable capacity with typically higher investment but lower operating costs. The $CO_2$ cap will also change capacity investment and generation mix as generators move to less carbon-intensive options. Other aspects of the electricity price change include reduced transmission and distribution costs due to decreased electricity generation from centralized plants, additional public benefits charge and increase or addition of emissions allowance costs and renewable energy credits in the electricity prices (see below). Natural gas prices also differ between the *Base Case* and the *PowerSwitch! Case* reflecting the effect of natural gas demand on natural gas prices. As natural gas demand decreases (following lower electricity demand), natural gas prices to all sectors will also decrease, an additional benefit of the *PowerSwitch!* policies.

The *PowerSwitch!* policies result in higher electricity prices to all sectors; the average price is 2.4 cents/kWh higher in 2010 and 1.2 cents/kWh higher in 2020 (2000$). However when combined with lower electricity demand, lower fossil fuel demand and lower natural gas prices the buildings and industrial sectors have a net energy bill decrease in 2020 of $121 billion. The energy bill decreases from 2004 to 2020 result in average savings of $11 billion per year. Also, as described below, the increase in electricity price is dominated by revenues collected by the government, which would be returned to the public, thereby limiting any cost to consumers.

*Revenue transfers from cap and trade programs* are the revenues collected from the emission cap and trade and the renewable portfolio standard programs. We assume that the allowances from these programs are auctioned by the government—the electricity generators will increase their prices to consumers, to cover the costs of the allowances, but the government will return the auction revenues to the public. Thus, the policies are considered "revenue neutral." The distribution of the revenue will probably differ somewhat from the collection through higher electricity prices, but the overall impact on society will be a transfer. These revenue transfers are significant; the cumulative value from 2004 to 2020 reaches $350 billion.

*Incremental investments in efficiency and CHP* refers to the incremental cost of more energy efficient equipment plus additional CHP units for the residential, commercial and industrial sectors. The cumulative investments reach $248 billion by 2020.

Overall the policies in this study lead to net benefits to the U.S. economy that average $20 billion per year for the period from 2004 to 2020. The benefits and costs of the policy measures are at similar levels up to 2010 but benefits significantly outpace costs in later years, reflecting in part the longer term benefits of reduced costs as new technologies are commercialized and as the system adjusts to the new policies. By 2020, the average savings exceed the additional costs of new equipment by more than $80 billion per year.

### 6.3 Air Pollution Reductions

A variety of air pollutants associated with the use of fossil fuels can cause or exacerbate health problems and damage the environment. Reducing use of fossil fuels would reap important local health benefits by lowering the amount of air pollutants inhaled. Recent scientific findings confirm that pollutants such as fine particulates, carbon monoxide and ozone (formed by a mix of volatile organic compounds and nitrogen oxides in presence of sunlight) can lead to health damage, including premature death. Research shows that small children and the elderly are particularly at risk from these emissions (Dockery et al. 1993; Schwartz and Dockery 1992). The *PowerSwitch! Case* would reduce national, regional and local pollution, owing to reduced fossil fuel use and cleaner generating technology, providing important environmental benefits and health benefits, especially for small children and the elderly.

The cap and trade system reduces sulfur dioxide ($SO_2$) emissions from current emissions of 11 million tons to 2.87 million tons in 2010 and 2.27 million tons in 2016; cuts emissions of nitrogen oxides ($NO_x$) by power plants from current emissions of 5 million tons to 1.548 million tons in 2008; and cuts mercury emissions by power plants from current emissions of 48 tons to 5 tons in 2008. The emissions that we show for $NO_x$, $SO_2$ and mercury represent only the emissions from the electric sector. There are small additional reductions in the industrial and building sectors resulting from emissions decreases owing to decreased oil and natural gas combustion from greater boiler/furnace efficiencies, which exceed the emissions increases that come from the net increase in on-site natural gas combustion for CHP. While the reductions in

$SO_2$ and $NO_x$ from central station electricity generation exceed 6.8 and 3.5 million tons respectively, in 2020, we estimate that the net reductions in industry and buildings are 0.5 and 0.2 million tons, respectively. Thus the end-use impacts are about one order of magnitude lower than the electric sector impacts, but they are not negligible, especially when compared with the remaining emissions in the *PowerSwitch! Case*, which are quite low.

## 7 The Path to Zero-Carbon Power

The ultimate goal is stabilizing concentrations of heat-trapping gases in the atmosphere at levels that avert dangerous climate change. One key strategy to meet that goal is achieving zero-carbon electricity in the United States by mid-century. The policies described in this paper set the nation on the path to achieve that goal. The United States can achieve this and experience economic growth if we support the diverse portfolio of existing technologies and industries that produce energy efficiency and renewable energy and a smart set of policies, incentives and goals. This low-carbon blueprint can happen through a set of market incentives and user fees that are widely accepted by a wide range of the political spectrum. Adopting these recommendations would also cut other costly near term expenditures consumers are having to finance out of their own pocketbooks such as landfills, forest fires, pollution reduction and unreliable power—all multibillion dollar costs that are being incurred today.

Attempts to analyze the exact path to zero carbon dioxide beyond 2020 would be speculative at best. Certainly increased efficiency and reliance on renewable energy will need to be continued. The cost of some currently speculative technologies, however, will change over this longer timeframe and new technologies will develop. If we follow the policy and technology approach outlined in this report, the United States will be well placed to take advantage of new technologies and achieve the carbon-free target.

Fortunately, many of the policies recommended in this study will make such acceleration easier and cheaper by fostering the development of new clean energy technologies and reducing the cost of existing clean energy technologies through increased market penetration. Some technologies that have only modest impact by 2020, such as solar photovoltaics and fuel cells, can be expected to be significant contributors to reducing heat-trapping gas emissions by mid-century. Familiarity with carbon dioxide trading will make it that much easier to reduce the caps post 2020 and since the electric grid will be generating far lower amounts of $CO_2$ in 2020 than today, the potentially higher $CO_2$ prices would have an increasingly smaller impact on the U.S. economy, consumers and businesses.

Some are advocating an additional strategy for reducing net atmospheric $CO_2$ emissions: carbon sequestration. Sequestration involves removing carbon from carbon-based fuels or removing carbon dioxide from waste streams or from the atmosphere and storing it within the planet's biological and physical systems. Various pathways have been proposed for carbon sequestration including forests and soils, geological formations (such as underground aquifers) and the deep oceans. The technical potential for each of these options may be large. However, concerns remain regarding potential harm to the environment and questions about whether these strategies will be cost-effective compared with other alternatives. Ocean sequestration has been shown to pose serious environmental risks and is unlikely to be a viable climate mitigation strategy. Biological sequestration can, with appropriate accounting rules and environmental criteria, play a role in reducing atmospheric concentrations of $CO_2$ in the near term. Costs for geological sequestration are currently quite high, but are likely to decrease in the coming decades, as it is the subject of considerable corporate, academic and government research. Since even small leakage rates (1 percent per year) can undermine the environmental value of such sequestration, a considerable amount of testing will have to be done before this approach can be considered for widespread use as a major $CO_2$ mitigation strategy.

## 8 Conclusions

Our analysis showed that by 2020 it will be possible to dramatically reduce $CO_2$ emissions in the U.S. power sector while producing substantial savings to American consumers and businesses. The result is a substantial transformation of the electric generation sector, leading to a more balanced portfolio that is not overly dependent on any one fuel or large centralized power plants.

In order to achieve these reductions, policies should be implemented as soon as possible to accelerate the shift away from carbon-intensive fossil fuels and towards energy efficient equipment and renewable sources of energy. Such action would lead to reductions in heat-trapping carbon dioxide emission of about 70 percent relative to business as usual in 2020 and by about 60 percent compared to current levels. Furthermore, emissions of other pollutants would also be reduced, thus improving local air quality and public health.

No single policy can achieve this goal, but rather the United States needs a broad set of national policies to increase energy efficiency, accelerate the adoption of renewable energy technologies and shift energy use to more efficient power systems, including onsite cogeneration. The *PowerSwitch!* portfolio of policies and measures would bring overall economic *benefits* to the United States, since lower electricity bills would more than pay the costs of increased investment in clean power sources and implementation of clean energy programs. By 2020, the savings in the energy bills of consumers and businesses would exceed costs by more than *$80 billion a year*.

While implementing this set of policies and measures is an ambitious undertaking, it represents an important transitional strategy to meet the long-term requirements of climate protection. It builds the technological and institutional foundation for much deeper long-term emission reductions needed for climate protection. Such actions would stimulate innovation and invention here in the United States while positioning the country as a responsible international leader in meeting the global challenge of climate change.

## Appendix 1 - About the Contributors

This paper was written by the Center for Energy and Climate Solutions (CECS) and Tellus Institute. CECS is a one-stop shop for helping companies and states design high-leverage strategies for cutting energy costs and reducing air pollution, including heat-trapping gas emissions. The Center is a division of the Global Environment & Technology Foundation (GETF), a Virginia-based nonprofit dedicated to building the infrastructure for sustainable development. GETF facilitates the demonstration of new technologies and ways of doing business and helps make these ideas accessible and replicable throughout a number of sectors. We look for innovative technologies and partnerships that can significantly contribute to this goal.

Since its inception in 1998, the Center has developed best practices and high-quality case studies on corporate heat-trapping gas mitigation and energy efficiency. These were published in the 1999 book *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions*. Since 1999, CECS has helped World Wildlife Fund manage its Climate Savers program in the United States, which encourages major companies to make GHG commitments. Climate Savers companies include IBM, Johnson & Johnson, Polaroid, The Collins Companies, LaFarge and Nike.

Tellus Institute is a not-for-profit organization conducting research for over twenty-five years. Environmental stewardship and equitable development lie at the core of the vision of sustainability and at the heart of the Institute's mission. Tellus conducts a diverse program of research, consulting and communication, addressing policy and planning environmental and social issues in such areas as energy, water, waste and land use at various levels -- global, national, regional, state, community and corporate. The Institute brings a keen awareness of the linkages that cut across spatial levels and across environmental, social and economic dimensions. Its sponsors include foundations, government agencies, multilateral organizations, non-governmental organizations and business.

The Tellus Energy Group provided the core analyses for the PowerSwitch project and over the past several years has provided WWF and others with analyses of policies and measures for heat-trapping gas mitigation in the United States, most recently America's Global Warming Solutions. The group provides analyses for government agencies, policy-makers and citizen groups throughout North America, on energy and environment scenarios, technology and economic assessments, policies and regulatory frameworks. Project areas include: climate protection; markets, pricing and regulation; and sustainable energy production and consumption and transportation strategies. The other Tellus groups focus on sustainable communities, business and sustainability and global/regional sustainable development.

## Appendix 2 – Analytical Approach

Our approach for this analysis consists of estimating electricity demand reductions and investment costs due to electricity efficiency and distributed electricity measures based on recent analysis from U.S. sources. These electricity demand reductions will then be combined with electric sector policies (renewable energy standards, emission caps or taxes) within the National Energy Modeling System (NEMS) to simulate the response in the electric sector (avoided costs, avoided $CO_2$ and other emissions, incremental power supply costs, supply/demand/price feedback effects, etc.).

NEMS is the primary energy forecasting and policy analysis model developed and used by the Energy Information Administration (a branch of the U.S. Department of Energy). NEMS models electricity demand/supply interactions by dividing the United States into 13 National Electricity Reliability Council (NERC) regions, some of which embody or approximate power pools. The model ensures that supplies are developed and dispatched to meet the demands in each region, taking account of system reliability, the capital, fuel and O&M costs of new power plant options, the operating costs of existing units, the efficiencies and outage rates of all power plants, transmission and distribution system costs and losses, inter-regional sales and purchases, state renewable energy requirements and national and regional pollution cap and trade systems. Prices for fuels used in the electric sector (natural gas, coal, biomass, fuel oil) are determined endogenously – depending on demand for these fuels. NEMS is able to capture the benefits of lower electricity demand leading to lower natural gas demand, which results in lower natural gas prices for all users. Similarly, NEMS captures the additional burden of higher natural gas demand (for example, due to early retirement of coal plants) leading to higher natural gas prices for all users.

NEMS provides information on:

- Amount and type of electricity generation, including non-utility generation, fuel use, imports and exports;
- $CO_2$, $SO_2$, $NO_x$ and mercury emissions; and,
- Costs for new capital investments, fuel and operations, transmission and distribution.

The NEMS analyses are used to determine national costs and emission reductions by comparing a base case scenario with a scenario containing the electricity sales reductions (owing to greater end-use efficiency) plus supply-side measures (renewables, emissions caps, etc).

Details on the modifications that we made to the *Base Case* and the estimates of electricity reductions from the demand and cogeneration policies are included in Appendix Three, which can be found at http://www.worldwildlife.org/PowerSwitch. Further information on NEMS is available from the Energy Information Administration's website, http://www.eia.doe.gov/bookshelf/docs.html

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