CLEAN ENERGY SOLUTIONS

Colorado's Potential to Reduce Global Warming Pollution and Public Health Damage with Energy Efficiency and Renewable Energy

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EXECUTIVE SUMMARY

As Colorado's population continues to boom and national energy markets struggle for stability, state officials are presented with the challenge of securing reliable electricity sources at stable prices. In this reassessment of long-term energy policy, Colorado has the opportunity also to reduce power plant pollution, a principal source of global warming gases, public health damage, and ecological degradation.

The current energy system relies almost entirely on dirty fossil fuels. We now have the opportunity to choose alternative fuel sources and new technologies to clean up our future. Ample clean, renewable resources and energy efficiency technologies can provide us with stable, reliable, and cost-effective electricity while reducing pollution.

Traditional Power Production Promotes Global Warming and Damages Public Health

Today's electric power industry is the most polluting industry in the nation. The electric power industry is responsible for 40% of U.S. carbon dioxide (CO_2) emissions. The Colorado electricity industry emits 1,200 pounds of CO_2 more per person each year than the U.S. average.

CO_2 is a principal cause of global warming, perhaps the most serious environmental challenge of our time. Global surface temperatures have been rising over the past century at unprecedented rates and will continue to increase if greenhouse gases are not stabilized.

Power plants are also the largest industrial source of sulfur dioxide, nitrogen oxides, and mercury, which cause severe public health damage.

In the short term, a wholesale shift away from fossil fuels toward clean energy sources is a crucial strategy for reducing these impacts.

Renewable Energy Sources and Energy Efficiency Can Help Meet Our Energy Needs

Renewables and energy efficiency have advanced technologically and commercially to the point where they are now ready for wide-scale development. Huge untapped potential exists at both the state and national levels.

Colorado Clean Energy Sources

Colorado is one of the top ten states for renewable energy potential. By 2010, more than a quarter of the state's projected electricity needs could be met with wind power. Nearly all of this potential remains untapped today, with dirty coal meeting 93% of Colorado's power needs.

- The state has the potential to capture up to 183,000 peak MW of wind power. 5,000 MW of this could come on line by 2010.

Colorado also has tremendous energy savings potential.

- If the state were to invest 1.5% of annual utility revenues in demand-side management and energy efficiency, Colorado could reduce anticipated total electricity demand by 10% within five years.

By embarking on a strategy to develop Colorado's wind and energy savings potential, the state could cover all of its demand growth through 2010 with clean sources and reduce the use of coal by the equivalent of one large power plant.

National Clean Energy Sources

Nationally, renewable energy production has moved from its infancy to become a significant source of power with the potential to grow exponentially in the next few years and beyond. By 2010, 125,000 MW of renewable energy capacity could be operational, enough to replace 80 large fossil fuel power plants.

- The U.S. has 2 billion peak MW of wind power potential, nearly twice the nation's current demand. By 2010, 116,000 MW of that untapped potential could come online.
- The western states have 22,000 MW of geothermal power potential. By 2010, 5,600 MW of new geothermal energy capacity could come online.
- Solar energy could theoretically generate more than enough electricity to satisfy the entire U.S. By 2010, 1,000 MW of solar thermal resources could feasibly be developed, and photovoltaic capacity could reach 3,000 MW.

Within the same time frame, implementation of energy efficiency-promoting policies could cut the nation's electricity demand by 15%, saving 72,000 average MW annually.

Renewable Energy and Energy Efficiency Reduce Global Warming Pollution

Colorado would reduce annual CO_2 emissions by as much as 30%, or 15 million tons, by developing 5,000 MW of wind power and reducing its electricity demand by 10% through energy efficiency by 2010 rather than continuing on the current path. This would also reduce health-damaging pollution by 28%.

Nationally by 2010, energy efficiency and renewable energy development at the levels described above would enable the U.S. to reduce CO_2 emissions by as much as 37%, or one billion tons annually compared to projections for the current path. Health-damaging pollution would also be reduced by as much as 43%.

Renewable Energy and Energy Efficiency Development Is Economical

The best wind, solar, and geothermal projects can produce electricity at a lower cost than fossil fuels when external life-cycle costs of electricity generation are taken into account.

The cost of wind power is expected to drop in the near future from 5.6 to 2.6 ¢/kWh. This is far cheaper than both natural gas and coal, which cost an average of 6.0 ¢/kWh and 8.8 ¢/kWh, respectively, when life-cycle costs are included.

Energy efficiency provides the cheapest, quickest, and cleanest way to address urgent power needs. Nationally, utilities have saved between 25,000 and 30,000 MW each year - the equivalent of 100 large power plants - over the past five years through energy efficiency programs. The programs averaged 2.8 cents/kWh, a cost that is less than that of energy from most new power plants, even when life-cycle costs are excluded.

Together, renewable energy and energy efficiency development provide the best overall strategy for America's new energy future. Several recent studies examining the economic impact of efficiency and renewables stimulus programs found that with policies encouraging renewables and energy efficiency, the nation's economy would grow more than under a business-as-usual scenario.

Renewable Energy and Energy Efficiency Development Leads to More Jobs

Electricity generation from renewable energy involves a higher proportion of its costs for labor as compared to fossil fuel electricity generation, in which much of the cost goes to fuel. Wind and solar photovoltaic operations each provide 40% more jobs per dollar than coal operations.

The challenge of meeting stricter energy efficiency goals would also require increases in employment.

Implementing a suite of policies encouraging both renewable energy and energy efficiency development would lead to net increases in employment in the U.S. and in each individual state. Colorado would see a net gain of 10,000 jobs, while the U.S. as a whole would gain more than 700,000 jobs by the year 2010.

Comprehensive Energy Policies Are Needed

Energy policy on the local, state, and national levels must address four key priorities:

- Energy conservation and efficiency.
- Promotion of clean, renewable energy sources.
- An end to wasteful subsidies for fuels and technologies that are neither clean nor sustainable.
- Promotion of more local control and democratic governance over energy.

INTRODUCTION

Colorado is blessed with abundant resources. In addition to the beautiful vistas and fertile land, the state has more than enough wind, sunshine, and geothermal resources to power every home, business, and factory. Yet we are using almost none of these valuable resources. Instead, we are generating electricity using fossil fuels, which pollute Colorado's air, land, and water, damage the health of Coloradans, and contribute to global warming.

Current plans are to continue down this dirty and dangerous path. All but one newly planned power plant project in the state are fossil fuel-fired. These plans are taking a bad situation and making it worse.

Damages from global climate change brought on by this fossil fuel use would be felt here in Colorado in the form of increases in insect- and rodent-borne diseases, longer droughts punctuated by heavier rains, and other ways. Already, the state saw the emergence of hantavirus pulmonary syndrome in the Four Corners area with the upsurge of rodent populations that accompany extreme weather. The population of deer mice, the primary carrier of the disease, could proliferate again under a longer drought scenario that would kill off many of its predators.

Water supplies in the state are already of major concern. The U.S. Environmental Protection Agency found that the hydrology and water supply system of the Colorado River Basin are extremely sensitive to climatic changes that could occur over the next several decades. If temperatures increase without increases in precipitation, runoff into the Colorado River would be reduced. An increase in temperature of 2°C would reduce runoff by 4-12%, and an increase of 4°C would reduce runoff by 10-20%.[1] Under long-term reductions in runoff, reservoirs managed under existing rules would be drawn almost completely dry, electricity generation from hydropower in the basin would drop dramatically, and the water would frequently exceed current health standards for salinity.

As a nation, events of the past year, including market-based energy shortages on the West Coast, the 9/11 terrorist attacks, and war in the Middle East and Central Asia, have led us to the brink of a crucial decision. Do we stay on the same old unreliable, polluting, and insecure path? Or do we shift to a new clean energy path, meeting the nation's ever-growing power needs with sustainable, domestic energy sources that enhance national security and mitigate against further warming of our atmosphere? This report shows how we are now able to choose the clean energy path and why it is the better choice both environmentally and economically. We can simultaneously meet our growing electricity needs, reduce pollution contributing to global warming, and grow our economy.

Colorado has the resources to become one of the top ten clean energy-producing states in the nation. The state has capitalized on its fossil fuel resources for decades, but now Colorado must recognize that it is time to change and capitalize on its nearly unlimited clean energy resources. Now is the time to implement clean energy solutions.

PART I: HEALTH AND ENVIRONMENTAL IMPACTS OF CONVENTIONAL ELECTRICITY PRODUCTION

Conventional electricity production using fossil fuels involves the excavation and combustion of fossil fuels, both of which cause severe environmental and public health damage.

Impacts of Fossil Fuel Burning

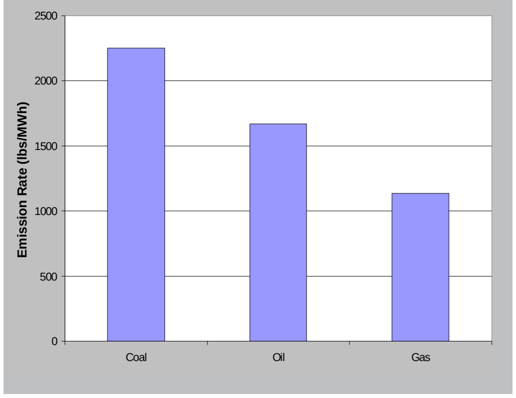
Electricity generation in the U.S. is responsible for:

- 40 percent of emissions of carbon dioxide, a principal global warming gas.[2]
- 67 percent of the nation's emissions of sulfur dioxide, a precursor of fine particulate matter, acid rain, and regional haze.[3]
- 23 percent of emissions of nitrogen oxide, a precursor of ground-level ozone (smog), particulate matter, acid rain, global warming, nitrogen overloading in waterways and forests, and regional haze.[4]
- 33 percent of emissions of man-made mercury, a toxic metal that bioaccumulates in animals and spreads through the food chain to humans.[5]

In Colorado, electricity generation is responsible for:

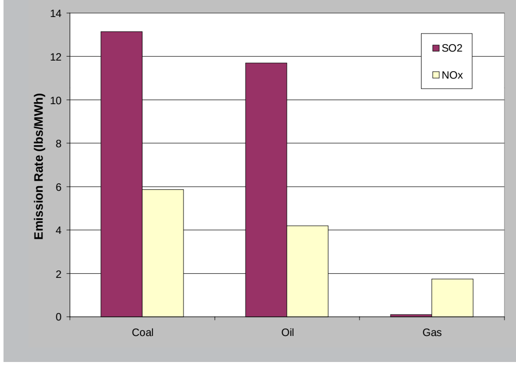
- 48% of the state's emissions of carbon dioxide.[6]
- 87% of the state's emissions of sulfur dioxide.[7]
- 61% of the state's emissions of nitrogen oxide.[8]
- 57% of the state's emissions of man-made mercury.[9]

Figure 1: CO_2 Emission Rates of Power Plants Burning Fossil Fuels[10]



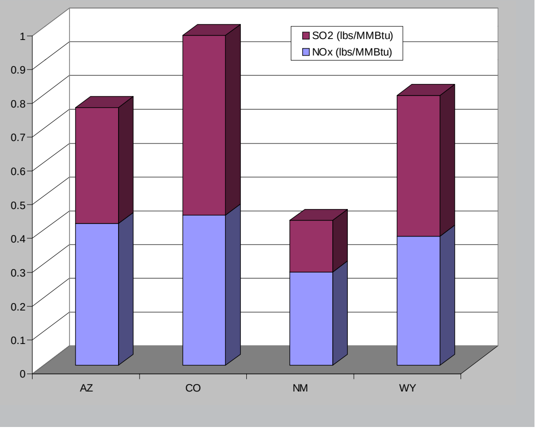
All fossil fuel-burning power plants pollute the air to varying degrees. Coal-fired power plants are by far the dirtiest. Oil-burning power plants emit less pollution than those using coal, but more than natural gas-fired plants. Natural gas produces cleaner emissions than other fossil fuels, but U.S. power plants burn enough of it to produce hundreds of millions of tons of CO_2, the dominant greenhouse gas, each year. In Colorado, the amount of power plant CO_2 emissions translates to about 15 pounds of CO_2 produced per person each day.

Figure 2: SO_2 and NOx Emission Rates of Power Plants Burning Fossil Fuels



Although coal is the energy source used to generate 52% of electricity in the U.S., coal-burning power plants account for 87.5% of the CO_2, 95.2% of the SO_2, and 90.9% of the NOx emitted collectively by all electric power plants.[11]

Figure 3: Emission Rates of Fossil Fuel Power Plants in the Western Mountain Region[14]



In Colorado, coal is used to generate nearly all (93%) of its electricity needs. Coal-fired power plants emit 99% of the total power plant CO_2 emissions in the state.[12] Colorado power plants also have the highest rate of fossil fuel emissions in their region.[13] For every kilowatt-hour of electricity Colorado generates, it emits more pollutants than neighboring states.

Global Warming and Carbon Dioxide

Global warming is perhaps the most serious environmental challenge of our time. The world's leading climate scientists, economists, and other experts formed the Intergovernmental Panel on Climate Change (IPCC) in 1988 to verify the recent dramatic increase in the earth's temperature and to identify its causes and consequences. What they have found is alarming.

- The average daytime global surface temperature rose 0.6°C (1.08°F) over the 20th century. The average nighttime minimum surface temperature over land, the more indicative measurement of global temperature change, rose an average of 0.2°C per decade since 1950.[15]
- The 1990s were warmer than the 1980s, previously the warmest decade on record. The warmest year on record was 1998.[16]

The IPCC predicts that if greenhouse gas emissions are not stabilized, the average global surface temperature will increase by 1.4 – 5.8°C between 1990 and 2100.[17] This level of increase is put into perspective by the fact that during the last ice age (about 18,000 years ago), the earth was only 9 degrees cooler than it is now.[18]

The impacts of warmer global temperatures are predicted to include many serious and broad-ranging effects, some of which have already begun:

- Increased frequency and intensity of heat waves, fires, droughts, rainfall, and flooding;
- Rising sea levels that overtake islands and coastal areas;
- Disruption and loss of ecosystems, pushing species to extinction and rendering historically fertile farmland unproductive;
- Increased geographic range and virulence of infectious and tropical diseases.

Although natural variations in the output of the sun can contribute to climate change, the IPCC has found that natural contributions are minimal compared to the effects of greenhouse gases. Greenhouse gases trap heat in the earth's atmosphere, exaggerating the natural greenhouse effect and warming the earth. Carbon dioxide (CO_2) is by far the most abundant greenhouse gas. The atmospheric concentration of CO_2 has increased by 31% since 1750.[19]

In its latest update on climate change, the IPCC concluded, "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."[20] Fossil fuel burning accounts for three-quarters of the CO_2 emissions associated with human activities. The U.S. electric industry alone, which accounts for 40% of the total U.S. CO_2 emissions, emits more CO_2 than the total CO_2 emissions from any other nation.

Soot and Sulfur Dioxide

Power plants are by far the largest source of sulfur dioxide (SO_2).[21] More than 12,000 of the nearly 19,000 tons of SO_2 the nation emits annually comes from electric power plants. SO_2 makes up the largest component of fine particulate matter, or "soot".[22] Particulate matter is the type of air pollution that is visible in the air - ash, dust, and acid aerosols.

When inhaled, these tiny particles become deeply imbedded in the lungs. The particles cannot be expelled by coughing, swallowing, or sneezing. As they sit in the lungs they cause varying degrees of irritation, which can lead to loss of heart and lung function. Health consequences range from bronchitis and chronic cough to death.[23] Fine particulate matter is of most concern to vulnerable populations, including young children, the elderly, and those with asthma or other respiratory diseases. The Natural Resources Defense Council estimates that more than 60,000 lives are cut short each year in the U.S. due to fine particulate pollution.[24]

Particulate air pollution can travel far distances from its source. The visual effect of particulate air pollution is referred to as haze. Haze has spread so far as to infiltrate some of America's most pristine national parks, posing health risks to those who use the parks for recreation.

Smog and Nitrogen Oxides

Power plants are the largest industrial source of nitrogen oxide (NOx) pollution, which causes formation of ground-level ozone (also known as smog). Ozone is our nation's most prevalent and well-understood air contaminant. Despite reductions in smog levels since the passage of the Clean Air Act in 1970, today an estimated 117 million people live in areas where the air is unsafe to breathe due to ozone.[25] In 1999, the ozone health standard adopted by the EPA in 1997 was exceeded 7,200 times.[26]

Ozone is an invisible, odorless gas, which is formed when nitrogen oxides mix with volatile organic compounds (reactive man-made chemical air pollutants) in the presence of sunlight. Public health is most at risk during "ozone season," from mid-May to mid-September in most places, when there is plenty of sunlight.

When inhaled, ozone at high concentrations can oxidize or "burn through" lung tissue. Breathing ozone at high concentrations can cause airways to the lungs to become swollen and inflamed. Eventually, this causes scarring and decreases the amount of oxygen that is delivered to the body with each breath. The corrosive effect of exposure to ozone in the respiratory system increases susceptibility to infections. Outdoor exercise on days when ozone concentrations are high increases the impact on the respiratory system.

As is the case with soot, ozone poses a more serious health threat to vulnerable populations, including children, the elderly, and people with asthma or chronic pulmonary disorders (including chronic bronchitis and emphysema). A number of studies have linked ozone pollution with increased frequency of emergency room visits, including one study of 25 hospitals that found high ozone levels were associated with at least a 21% increase in emergency room visits for people aged 64 and older.[27]

Ozone has also been linked to increased frequency of asthma attacks. On high-smog days, children with asthma are 40% more likely to suffer asthma attacks compared to days with average pollution levels.[28] A 1999 Abt Associates study estimated that more than six million asthma attacks were triggered by smog during high-ozone smog season in 1997.[29] Another study found a 26% increase in the number of asthma patients admitted to emergency rooms in New Jersey on summer days when ozone concentrations were high.[30]

Acid Rain, Sulfur Dioxide, and Nitrogen Oxides

Sulfur dioxide and nitrogen oxides do their damage not only via airborne ozone and particulates, but also by causing acid rain, which threatens entire forest and aquatic ecosystems. Once emitted into the air, sulfur and nitrogen oxides form sulfates and nitrates respectively, which are the principal components that change the pH of rainwater from neutral to dangerously acidic.

Acid in rain, clouds, and fog damages trees in two primary ways:

1) directly damaging the needles and foliage, making them unusually vulnerable to adverse conditions including cold temperature, and
2) depleting nutrients from the soils in which the trees grow.

Acid clouds and fog generally have even higher concentrations of damaging sulfates and nitrates than acid rain. Thus, acid deposition is linked to the decline of red spruce growing at high elevations and in coastal areas, both of which are immersed in acid clouds and fog for long time periods.[31]

Lake and stream ecosystems are also vulnerable to the effects of acid rain. As the acidity of the lakes and streams increases, the number of species that can live there declines.[32]

Nitrogen Loading and Nitrogen Oxides

Nitrogen oxide emissions from power plants are a major contributing factor to nitrogen loading in water bodies across the United States. Too much nitrogen causes algae blooms, which deplete the oxygen and kill marine life as they decay. Algae blooms also block sunlight that fish, shellfish, and aquatic vegetation need to survive. Nitrogen oxides released into the air can be carried hundreds of miles by the wind and fall into lakes and rivers.

The effects of nitrogen loading can be devastating for plant and animal life in these water bodies, as well as for people who depend on these waters for tourism, subsistence fishing, commercial fishing, and recreation.

The Toxic Food Chain and Mercury

Mercury is a toxic heavy metal that persists in the environment once it is released. When ingested in its methylated form, mercury can cause serious neurological damage, particularly to developing fetuses, infants, and children.[33] The neurotoxic effects of low-level exposure to methylmercury are similar to the effects of lead toxicity in children, and include delayed development and deficits in cognition, language, motor function, attention, and memory.[34]

Numerous species of fish in thousands of bodies of water across 41 of the 50 states contain such high levels of toxic methylmercury that health agencies have warned against eating them. The number of consumption advisories due to mercury poisoning increased 8% from 1999 to 2000 and 149% from 1993 to 2000.[35]

People most at risk include women of child-bearing age, pregnant women and their fetuses, nursing mothers and children, and subsistence fishers. Large predator fish such as largemouth bass, walleye, shark, tuna, and swordfish have higher levels of methylmercury in them than smaller species lower in the food web.[36] People who frequently and routinely consume fish (i.e. several servings a week), those who eat fish with higher levels of methylmercury, and those who eat a large amount of fish over a short period of time (e.g., anglers on vacation) are more likely to be exposed to higher levels of mercury.[37]

Mercury's primary entrance into the human diet occurs when mercury is emitted into the air and undergoes photochemical oxidation, forming oxidized mercury. Oxidized mercury is water-soluble and is deposited to land, lakes, and streams by rain and snow, where it reacts with bacteria to form methylmercury, the form most toxic to humans.[38] Methylmercury bioaccumulates to the greatest extent in the tissue of fish and other aquatic organisms and persists forever in the environment, magnifying its public health impacts.

Based on emission estimates for 1994-95, coal- and oil-burning power plants are the largest stationary sources of mercury emissions (32.8%), followed by municipal waste incinerators (18.7%), commercial and industrial boilers powered by coal or oil (17.9%), medical waste incinerators (10.1%), and hazardous waste incinerators (4.4%).[39]

Other Impacts
Energy Production

The process of excavating fossil fuels is extremely harmful to the environment. Coal and natural gas, the two main fossil fuels used in electricity production, are retrieved by different methods due to their locations in the earth and differing properties.

Coal Excavation

Mining for coal is a dirty, dangerous, and destructive process. It contaminates the land, surface water, groundwater, and air. To get to the coal, enormous chunks of earth are dug up from the surface or displaced by removing mountaintops (surface mining), or are excavated from beneath the ground (underground mining) and discarded into waste piles. Wildlife habitat, agricultural crops, forests, rangeland, and deserts are destroyed and replaced by pits, quarries, and tailing piles. Reclaiming a coal mine (replacing vegetation and restoring the landscape) helps reduce permanent disruption, but in spite of restoration efforts, original ecosystems may be replaced by completely different ecosystems, and hundreds of thousands of acres of mines have been abandoned rather than restored.

Water pollution is an enormous problem of coal mining. Waste piles of excavated dirt, which are normally secured under the surface and serve as natural water filters and physical support of the land, deposit toxic heavy metals and sediment that pollute and alter the course of local waterways. More waste from the washing of mined coal is added to these piles that grow on the order of tens of millions of tons per year.[40] Underground mining can contaminate as well as physically dislocate entire underground reservoirs that serve as drinking water supplies for many Americans.

The Western Pennsylvania Coalition for Abandoned Mine Reclamation calculated the cost of cleaning up pollution from old coal mines in Pennsylvania to be $15 billion, although they believe it's likely that estimate is low.[41] The U.S. Bureau of Mines estimates that the U.S. spends over $1 million each day to treat acidic mine water.[42] The cost of cleaning up abandoned lands that had been used for mining coal is $10,000 per acre.[43]

"Clean coal" has been touted as the solution to the horrendous environmental legacy of coal, claiming energy can be harnessed from coal without causing environmental damage. Although clean coal measures involve more responsible management of coal-generated pollution, the actual pollution reduction is marginal and air pollution mitigation strategies ultimately redirect the toxins and emit them into the environment through different routes (like the land or water). "Clean coal" techniques also encourage increased coal use in the long term. The General Accounting Office recently concluded that federal spending on "clean coal" technology has been a waste of money.[44]

Natural Gas and Coalbed Methane Excavation

When natural gas is retrieved from reservoirs, the construction of roads and gas pipelines destroys huge amounts of wildlife habitat. Transporting the gas, which is explosive by nature, is increasingly dangerous as the U.S. pipeline infrastructure ages. One quarter of the nation's natural gas pipelines is more than fifty years old.[45] Over the past decade, the number of serious accidents has steadily increased.[46]

Natural gas is often found in association with oil. The damage occurring from oil drilling and transport is probably the best known of the environmental impacts of fossil fuel excavation, due to the regularity of oil spills and the duration of their scathing effects. However, less known is the fact that leaks commonly go undetected, accounting for hundreds of thousands of gallons of spilled petroleum liquids each year.[47]

The most destructive process used to access natural gas from oil-free reservoirs is coalbed methane excavation. Coalbed methane differs from natural gas only slightly in its chemical makeup. Natural gas is mostly methane with some other hydrocarbon gases in its mixture. Coalbed methane is almost always pure methane.

Coalbed methane is found trapped in subsurface coal beds. To release the gas from the porous coal, coal seams are fractured with toxic fluids. Massive volumes of water must be pumped from underground aquifers, which often serve as the only drinking water source for local communities. The water, often containing high levels of sodium, arsenic, and other contaminants, is dumped on the surface and into rivers.

In the San Juan Basin of southwestern Colorado and northern New Mexico, the costly consequences of coalbed methane development are clear. The excavation process, along with the construction of roads and pipelines to transport the gas, has destroyed wildlife habitat and contaminated drinking water. Methane and hydrogen sulfide seeps have forced some families from their homes.[48] Underground coal fires have caused the ground to collapse in one area, and it is uncertain whether the gas industry can prevent the underground fires from spreading.[49]

Development in the Powder River Basin in Wyoming is more advanced than the San Juan region. If the gas industry develops the region according to current plans, the estimated cost to the state to address the water loss and contamination will be $320 million dollars, after accounting for severance tax credits the state will receive from the gas industry.[50]

Colorado water basins could see similar adverse economic effects if its coalbed methane reserves are further developed, as current trends suggest they will be. Coalbed methane's contribution to the nation's natural gas consumption rose from three percent in 1993 to seven percent in 1999. Colorado produced 35 percent of the nation's coalbed methane in 1999.[51]

Nuclear Waste

Nuclear fission, the reaction used to create energy in nuclear power plants, puts our lives at risk from potentially disastrous accidents and creates the most harmful substance known, for which there is no safe disposal process. Direct exposure to irradiated fuel from nuclear reactors delivers a lethal dose of radiation within seconds. According to the Department of Energy, 95% of the radioactive waste in this country (measured by radioactivity) is from commercial nuclear reactors. The storage of this waste poses a threat to water supplies throughout the nation. At the Hanford Nuclear Reservation in Washington, 67 of 177 underground tanks have leaked more than one million gallons of waste, contaminating groundwater and threatening the Columbia River.[52]

Presently more than 42,000 metric tons of spent fuel are in temporary storage in the U.S., with that number increasing by five metric tons every day.[53] This waste material will remain hazardous for the next 250,000 years.[54] The potential risk to human health is staggering. The total radioactivity of our spent fuel at this point is 30.6 billion curies. One single curie generates a radiation field intensity at a distance of one foot of about 11 rem per hour; the exposure limit set by federal regulation for an individual is 5 rem per year.[55] If a person were to stand within a yard from a 10-year old nuclear fuel assembly, within 30 seconds he would significantly increase his risk of genetic damage or cancer, and in less than 3 minutes he would receive a lethal dose of radioactivity.[56]

The risks of both catastrophic events and leakage of radioactive material into our environment pose great threats to our public health. Even low-level radiation has been linked to cancer, genetic and chromosomal instabilities, developmental deficiencies in the fetus, hereditary disease, accelerated aging, and loss of immune response competence.

The risk of accidents at reactors is also ever-present. Because many nuclear plants in the U.S. are decaying, the risk of accidents is greater now than it ever has been.

Further risk may come from transporting high-level nuclear waste. The nuclear industry has been trying for years to establish a single national nuclear waste repository. If such a facility were to be established, the risk of accidents and leakage would be immense. The Nevada Agency for Nuclear Projects recently calculated the risks of transporting nuclear waste using analyses by the Department of Energy and independent consultants. They concluded, “Accidents are inevitable and widespread contamination possible.”[57]

Part II: The Renewable Energy and Energy Efficiency Solution

Pollution is not an inevitable result of power production. Our energy future need not incorporate the same massive threats to the environment and public health that we face today. Clean energy sources in the form of renewables and energy efficiency have advanced technologically and commercially to the point where they are now ready for wide-scale development. Huge untapped potential exists at both the state and national levels. Using only renewable resources and energy efficiency, Colorado could meet all of its predicted growth in electricity demand through 2010 and replace the amount of electricity produced by one large coal-fired power plant. Nationally, renewable energy resources could meet 11% of U.S. electricity demand by 2010.

Investing in the development of clean energy sources will grow the economy more than will further investments in conventional fossil fuels. Today's best renewable energy projects produce power that costs less than fossil fuel-generated electricity, when the life cycle of the power production is considered. The cheapest and quickest way to meet urgent power demand is through energy efficiency.

Developing even just the small portion of the total renewable energy and energy efficiency potential outlined below will reduce pollution dramatically by 2010. Colorado would cut its power plant pollution by as much as 30%, while the nation as a whole would reduce power plant pollution by 37% compared to projections for the current path by 2010.

Finally, Colorado energy preferences are in accord with national trends, ranking renewable energy more desirable than conventional sources. In a 1999 National Renewable Energy Laboratory survey, Colorado homeowners ranked solar energy and wind power as the most preferred electricity sources when considering a number of factors, including environmental impacts, safety, cost, abundance, national self-reliance, meeting growing energy demands, stimulating economic development, diversifying the energy mix, adding high-tech jobs, and improving the economy.[58]

Renewable Energy and Efficiency Potential in Colorado

Colorado is one of the top ten states for renewable energy potential. However, virtually none of it is being tapped currently for electricity generation.[59] Coal provides an astonishing 93% of the energy used by Colorado utilities for electricity generation. Hydropower (4%), natural gas (3%), and a splash of oil (0.1%) provide the rest.

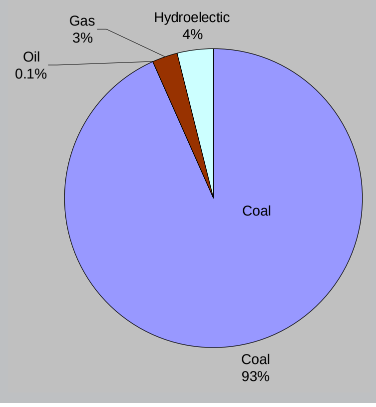


Figure 4: Colorado's 1998 Profile of Electricity Sources[60]

For the majority of the past 100 years, Colorado had no other real alternatives for its energy supply. Now, clean and affordable options are finally available. No longer do the people of Colorado have to trade their health and that of their land, air, and water in order to stay warm in winter and live with the modern conveniences that electricity gives us. By tapping its vast energy savings and renewable energy potential, the state can now dramatically reduce power plant pollution while cost-effectively meeting its growing electricity demand. By 2010, more than a quarter of the state's projected electricity needs could be met with renewable energy sources.

Wind Energy Potential

Colorado has enormous wind potential. The Pacific Northwest Laboratory (PNL) estimates the state could generate over 480,000 gigawatt hours per year (GWh/yr) of electricity from wind – over twelve times the state's demand in 1998. The National Renewable Energy Laboratory (NREL) made more conservative estimates, measuring wind potential only in areas that met stricter wind classifications and that were located within ten miles of existing transmission lines. Under these criteria, NREL estimated Colorado could generate over 204,000 GWh/yr of electricity annually, over five times the 1998 demand.[61]

In February 2001, the Colorado Public Utilities Commission ordered Xcel Energy to include a 162 MW wind project rather than additional natural gas capacity, stating it was "a cost-effective bid that should be included in the company's portfolio."[62] The 162 MW wind project will be operational by the end of 2002 if the federal production tax credit is reauthorized in time.[63]

If additions to the current wind power capacity of 60 MW in Colorado were to grow annually by 30%, total capacity would be 5,246 MW by 2010, generating more than 13,000 GWh/yr. Considering that the Colorado Public Utilities Commission's tri-annual integrated resource planning process may cause temporary lags in the installation of wind power, a conservative rounding to 5,000 MW of wind power by 2010 is appropriate. In practice, capacity may be added more sporadically rather than growing at exactly 30% each year.

Although a 30% growth rate may seem aggressive, it is quite feasible in Colorado. Wind power in Colorado has tremendous support. WindSource, an Xcel Energy program offering customers the opportunity to purchase wind power over conventional sources, is the largest customer-driven wind energy program in the nation. More than 17,000 people have signed onto the WindSource program to purchase 100 kWh blocks of wind power on a monthly basis for a premium of $2.50 for each block.[64]

This amount is a small portion of the total wind potential in the state, but developing it would nearly meet all of the state's pro-

Note on Units

Megawatts (MW) is a unit of measurement indicating how fast a plant can put out electrons. This is the standard measure of the generating capacity of a power plant. It is also used to determine if the total generating capacity on the grid is enough to satisfy demand at any one time.

MW denotes peak megawatts, as opposed to average megawatts (MWa). MWa is used to emphasize the intermittency of electricity generation from some sources. Wind power capacity, for instance, is often reported as MWa.

Megawatt-hours (MWh) is a unit measuring the total amount of electrons produced over some time frame. A 50 MW power plant operating at full capacity for one hour produces 50 MWh of electricity. This is the appropriate unit for talking about how much of the state's electricity was produced by various sources in a given time frame. To measure how much such a plant would produce in one year, simply multiply the capacity by the number of hours in a year (50 MW x 8,760 hrs/yr = 438,000 MWh/yr). 1,000 MWh equals one gigawatt-hour (GWh).

Table 1: Colorado Wind Power Capacity and Generation with 30% Annual Growth[66]

Year	Additions	Wind Capacity (MW)	Electricity Generation (GWh/yr)
2002	162	222	583
2003	211	433	1,137
2004	274	706	1,856
2005	356	1,062	2,792
2006	463	1,525	4,007
2007	601	2,126	5,588
2008	782	2,908	7,643
2009	1,017	3,925	10,315
2010	1,321	5,246	13,787

jected demand growth for utility electricity generation through 2010 (15,000 GWh/yr by 2010 at an annual growth rate of 3.0 percent).[65]

Solar Energy Potential

Colorado is ideally suited to harness power from the sun. With 300 sunny days a year on average, it stands at a distinct advantage over most of the U.S. for using solar energy. Only the southwestern desert receives more daily solar radiation on an annual basis than Colorado, according to U.S. solar radiation data recorded from 1961-1990.[69] The southern part of the state would be the most appropriate site for a solar thermal plant, but the entire state is well positioned for photovoltaics.

Solar Energy

There are two different types of technology for harnessing the sun's energy to generate electricity: solar thermal electric power plants and photovoltaics.

Solar thermal power plants use reflectors to concentrate sunlight on a receiver that uses the sun's heat to drive a turbine and generate electricity. Parabolic troughs, power towers, and dish/engines are the three technologies either in use or in development for solar thermal power plants, differing mainly in the shape and configuration of the reflectors.

Photovoltaics are very different from any other method ever used to generate electricity. All other methods require at least a two-step conversion of energy from its natural state into mechanical power and then to electrical power. Photovoltaic (PV) panels convert sunlight directly into electricity without the use of a generator or any moving parts.

The basic building block of this technology is the photovoltaic cell, which is made of semiconductor materials. Cells can be connected together to form modules, and modules can be connected to form arrays. In this way, PV systems can match power output to power needs. A few PV cells will power a hand-held calculator or wristwatch, while interconnected arrays can provide electricity for a remote village.

PV systems can operate either remotely or in connection with the utility grid. Their reliability even in adverse environments has been proven over decades by their performance powering satellites, which have to operate long-term with no maintenance. The Federal Emergency Management Agency now uses solar electricity systems for prevention, response, and recovery in emergency situations. It learned the value of PV for this purpose after Hurricane Andrew, when some Miami suburbs were without grid power for as much as two weeks. The PV systems that had previously been installed in that region survived and were able to help in the relief efforts.[67] With PV's long life, minimal operation and maintenance requirements, versatility (remote or grid-connected operation), reliability, and sustainable nature, the U.S. Department of Energy has concluded that, "it is easy to foresee PV's 21st century preeminence."[68]

Solar thermal collectors that use the sun's heat without converting it to electricity can also have an enormous impact on efforts to reduce demand for natural gas and electricity. These collectors are increasingly popular for heating swimming pools. When heating water in a residence, usually they serve as pre-heaters used in conjunction with another heating system, most commonly fueled by natural gas.

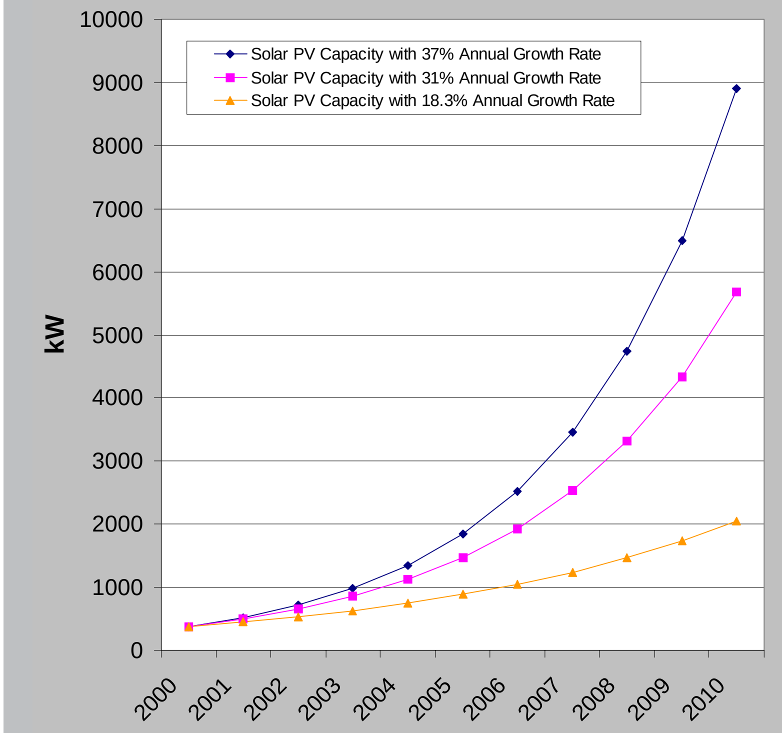
The question in Colorado, therefore, is not whether ample solar resources exist, but how soon solar energy projects can cost-effectively contribute to the state's electricity generation.

Cost is the biggest impediment to solar technology today. Like the other renewable energy technologies, nearly all of its costs are upfront capital costs. Although it is cost-effective over the lifetime of the system, solar technology has the greatest upfront capital costs.

The National Renewable Energy Laboratory analyzed policies and residential electricity rates in every state to determine today's breakeven turnkey cost (BTC) for a 1 kW installed PV system for each state. At the BTC, the consumer can pay for a PV system and neither gain nor lose money over the life of the system. While Colorado had a solar buydown program in place, the 1999 BTC cost for a PV system was determined to be $5,200/kW. An installed PV system cost $3,900/kW in 1999, down from $6,200/kW just three years prior. Hence, consumers who bought solar systems at 1999 prices will realize a $1,300/kW net savings over the lifetime of the system.[70]

Apparently, Coloradans recognized this golden opportunity. More

Figure 5: Colorado Solar PV Capacity Growth



than 100 solar systems were installed during the year and a half that the buy-down program was in place and sixty additional applications were turned down because the allotted funding had been exhausted. Unfortunately, installations have dropped dramatically since the rebate program ended.[71]

Installed PV systems to date in Colorado are estimated to total 382 kW.[72] If total installed PV systems increased at the same rate as the 1999-2000 national growth rate (18.5%), PV capacity would reach 2 MW by 2010. If, however, the state's total capacity were to grow at the global rate experienced from 1997-2000 (31%) or at the 1999-2000 global rate (37%), Colorado would have nearly 6 MW to 9 MW respectively.[73]

Geothermal Potential

The last nationwide geothermal resource assessment was published in 1978, and the state of knowledge about geothermal resources has advanced dramatically in the past 20 years.[74] A current reassessment is needed for Colorado as well as for other western states. The potential for high-temperature geothermal resources in Colorado is estimated to be 200 MW.[75] Experts now agree that this is an underestimation. No geothermal energy is tapped in Colorado for electricity production at this time.

Direct use of geothermal energy (use of geothermal energy to heat water or buildings without generating electricity) is an important application of the resource, which reduces demand for electricity. This is used at different locations throughout the state. The Colorado Geological Survey has identified

Geothermal Energy

Geothermal energy is the heat that flows constantly from the center of the earth, where temperatures are believed to reach 4,000ºC. Certain regions in the subsurface contain pockets where this thermal energy is concentrated. These regions can be tapped with a well to access the steam or hot water. The heat from the steam and hot water is then used to drive turbines that generate electricity.

Although most of the high-temperature geothermal resources capable of producing electricity in the U.S. are found in the western states, mid- and low-temperature resources are more abundant and widespread. Direct-use of geothermal energy and geothermal heat pumps transfer heat from the hot water accessed by a well to buildings and districts in order to heat water and air. Use of these resources can significantly reduce electricity demand.

56 areas of concentrated geothermal energy that could provide hot water and heat for 100,000 homes.

Biomass Potential

Colorado has good biomass resources. Because mixing biomass materials with coal can reduce the cost of coal-generated electricity, we can expect biomass use to grow. Where co-firing with biomass fuels replaces the use of coal, it will have a net benefit for the state, although it carries the risk of prolonging the viability of coal plants.

Current biomass power capacity in Colorado is 6.1 MW.[76] The Department of Energy estimates that Colorado could generate 5,200 GWh/yr of electricity using biomass. However, the state will need to assess the various types of biomass included in the DOE estimate to determine the environmental impacts and choose those that provide net benefits for the state.

Biomass Energy

Many types of “waste-to-energy” technologies and energy crops used to generate electricity fall under the banner of “biomass”. Some are unacceptably harmful to the environment, while others provide a net benefit to the environment.

Any material that releases air pollutants or toxins into the air upon combustion at a greater rate than the fossil fuel it is replacing should not qualify as a renewable fuel. Included in this group are municipal solid wastes (garbage) and construction debris, which can release dangerous toxins from the combustion of plastics and chemicals.

Burning timber wastes and agricultural wastes are also heavily polluting. Agricultural waste can either be turned back into the soil to maintain the long-term vitality of the topsoil or it can be used as biomass fuel for a biogas digester. Biogas digesters utilize bacteria to transform livestock manure or other organic compounds into fertilizer and biogas, which consists mainly of methane (the main component in natural gas). Biogas can be used for heating, cooking, and providing mechanical power and electricity. Normally, biogas digesters are primarily employed for waste (sewage) treatment and fertilizer production, and biogas-generated electricity is a secondary benefit.

In most cases, landfill gas used as a renewable fuel has a net benefit for the environment. When large amounts of methane are emitted from landfills, operators are required to flare it; when emissions fall below limits requiring flaring, methane and other toxins escape into the atmosphere. Therefore, burning the methane to generate electricity is more desirable.

Various types of energy crops (i.e. willow, sweetgum, sycamore, switchgrass, woody crops) hold the potential for cleaner electricity production compared to traditional fossil fuels, especially coal, but their life-cycle impacts on the environment need thorough assessment. Important considerations include:

- Land use that will be replaced – productive farmland, forests, and ecologically sensitive areas should not be sacrificed for energy crops.
- Effects on nutrient cycling and soil productivity.
- Use of herbicides and fertilizers compared to previous land use.
- Erosion potential and related water quality effects.
- Effects on biodiversity.
- Indirect promotion of unsustainable or ecologically harmful land practices (i.e. genetic engineering and deforestation).
- Effects on local economies.

In general, much research is still needed to determine how the life cycles of the various types of biomass used for electricity production affect pollution emissions and local ecosystems. Until such research is available, individual situations must be evaluated on a case-by-case basis. Until sustainable biomass technologies are developed and proven, the general definition of “renewable energy” should be reserved for wind, geothermal, and solar power. However, this report includes discussions of biomass potential because of its relatively wide usage and growing popularity.

Energy Savings Potential

Colorado has much room to grow in the area of energy efficiency programs and investments.

In 1998, Colorado spent 0.11% of utility revenues, $2.7 million, on energy efficiency programs, down from 0.40% in 1993. This spending yielded an annual energy savings equaling 1.26% of electricity sales in 1998, or 510 GWh/yr.[77]

These percentages are far below the national averages. In 1998, the national average for energy efficiency investment was 0.42% of utility revenues, which yielded average savings of 1.74% of electricity sales. The top five states, whose savings ranged from nearly 5% to more than 9% of their electricity sales, had each invested over 1% of utility revenues in energy efficiency programs.[78]

According to the Public Service Company of Colorado in April of 2000, if Colorado utilities were to invest 1.5% of their annual revenue in demand-side management and energy efficiency, they could reduce future electricity demand by 10% in five years.[79] Ten percent of Colorado's electricity generation projected for 2010 translates to about 5,000 GWh/yr, enough electricity to serve about 430,000 homes.

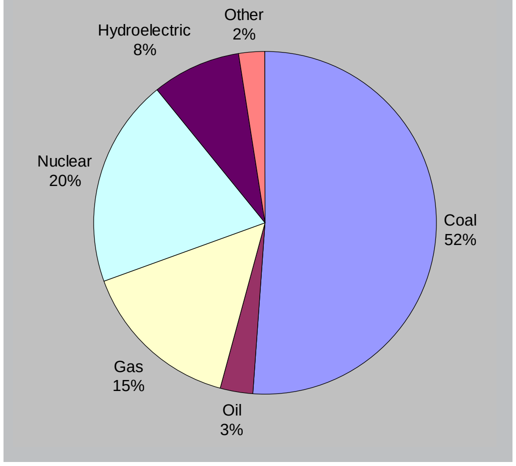
Combining utility energy efficiency programs with specific energy efficiency programs targeting other sectors like the appliance and building industries would yield greater results. Colorado is one of the top three states in total energy savings potential attainable from adopting stricter building codes.[80] According to the Alliance to Save Energy, Colorado could cut its electricity demand by over 65% while reducing carbon dioxide and other air pollutants by 23,000-34,000 tons annually through implementation of stricter building efficiency codes.[81]

The Hilton Hotel in Breckenridge demonstrates how current projects in Colorado are saving money now through energy efficiency measures. Breckenridge Hilton now saves $22,607 a year after simply switching to energy efficient lighting. High-use incandescent bulbs (60 to 150 watts) were replaced with two-piece compact fluorescent bulbs. The project cost $46,854 after accounting for the Public Service Company rebate of $14,200. Upfront investments will be paid back in 2.1 years.[82]

Individual households can also see significant savings in their electricity bills by implementing simple energy efficiency measures. Replacing incandescent light bulbs with compact fluorescent bulbs would save the average household $35-$60 annually. Weatherizing a home would reduce the household's energy expenditures by $200-$400 annually.[83]

National Renewable Energy and Efficiency Potential

Figure 6: 1999 U.S. Electricity Sources[84]



The nation's enormous renewable energy and energy efficiency potential remains largely undeveloped today. Despite the proven effectiveness and cost savings of energy efficiency and the evolution of affordable, clean technologies to produce electricity, the electric power industry continues to use coal for more than half (52%) of its electricity-generating needs. Other major sources include nuclear power, providing 20%, and gas, providing 15% of electricity. More minor contributions come from hydropower (8%), oil (3%), and other varied sources including non-hydro renewables (2%).

Together fossil fuels make up 70% of the electricity-generating sources in the U.S.

The Energy Information Administration predicts fossil fuel contributions will increase to 75% of total sources used to generate electricity by 2010.[85]

The U.S. has another choice. Renewable projects utilizing wind, geothermal, and solar energy are already operating throughout the country, proving the technology is ready to economically harness these resources. In 2000, wind energy contributed 2,970 MW, solar energy 550 MW, and geothermal energy 2,800 MW of power to the nation's energy system.[86] Together these resources generate about 32,000 GWh/yr of electricity, enough energy for 3.2 million American homes.

This amount merely scratches the surface of remaining untapped potential. By 2010, the U.S. could be cost-effectively generating 391,300 GWh/yr of emission-free electricity - more than eleven times the current amount of electricity it generates from renewable resources. With the projected electricity demand of 4,140,000 GWh/yr reduced by 15% through energy efficiency measures, non-hydro renewable energy sources could satisfy 11% of the nation's electricity demand by 2010.

Given the potentially catastrophic effects of global warming, it is very much in the best interests of Coloradans to encourage the federal government to facilitate the growth of renewable energy and energy efficiency across the country.

Table 2: Potential Growth of Clean Energy by 2010[87]

	Capacity (MW)			Generation (GWh/yr)	
Resource	**2000**	**New Development 2002-2010**	**2010**	**2010 Production**	**% of National Total 2010**
Wind	2,970	116,300	119,300	313,500	8.70%
Geothermal	2,800	5,600	8,400	70,000	1.90%
Solar PV	194	2,900	3,100	5,400	0.20%
Solar Thermal	354	1,000	1,300	2,400	0.07%
Energy Efficiency				630,000	17.50%
Total	**6,318**	**125,800**	**132,100**	**391,300**	**11%**

Wind Potential

The U.S. has enough windy spots to cost-effectively install more than a million MWa of wind power capacity, according to the Pacific Northwest Laboratory, a public/private research arm of the U.S. Department of Energy.[88] This would generate three times the amount of electricity the country used in 2000.[89]

Table 3: Future U.S. Wind Power Generation with 30% Annual Growth

Year	New Installation (MWa)	Total Capacity (MWa)	Total Generation (GWh/yr)
2000		891	7,805
2001	798	1,689	14,796
2002	1,037	2,726	23,883
2003	1,349	4,075	35,697
2004	1,753	5,828	51,055
2005	2,279	8,107	71,021
2006	2,963	11,070	96,976
2007	3,852	14,922	130,718
2008	5,007	19,929	174,582
2009	6,510	26,439	231,605
2010	8,462	34,901	305,736

The National Renewable Energy Laboratory made more conservative estimates in 1994, measuring wind-generating capability only in areas that met stricter wind classifications, that avoided environmentally sensitive areas, and that were located within ten miles of existing transmission lines. They estimated that the U.S. could generate 734,000 MWa of electricity from turbines in such locations – nearly twice as much as current demand.[90]

Wind power is the fastest growing energy source worldwide. New wind power capacity grew by 24% annually throughout the 1990s, with a growth rate of 37% in 1999 and 28% in 2000.[91] Last year, the industry installed enough turbines to generate an average of 798 MW in the U.S.[92] If new installations were to increase by 30% annually hereafter – a rapid but feasible rate – the country could generate more than 8% of its electricity from wind power by 2010, as depicted in Table 3. This modest proposal would tap only 35,000 MWa of the 734,000 MWa potential, but it would displace the need for 80 fossil fuel power plants.

Solar Potential

There is theoretically enough sunlight in a 100-mile square patch of desert in the southwestern U.S. to generate enough electricity for the entire country.[93] Solar thermal plants could replace 100% of current fossil fuel-based electricity production using only 1% of the earth's desert area.[94]

Although transmission distances may make generating all of our electricity in the deserts unfeasible, much development can take place before this presents a barrier. As a first step, we could easily hope to encourage the construction of 1,000 MW of solar thermal capacity with just five power plants in the Mojave Desert by 2010. As fuel cell tech-

Figure 7: Increasing Growth Rate of Worldwide Cumulative PV Capacity

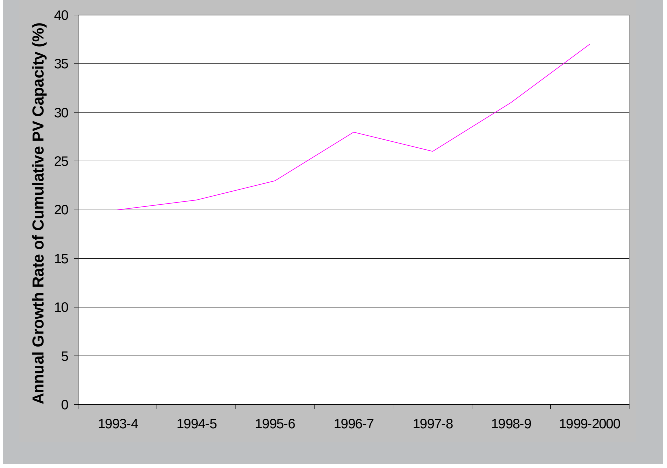
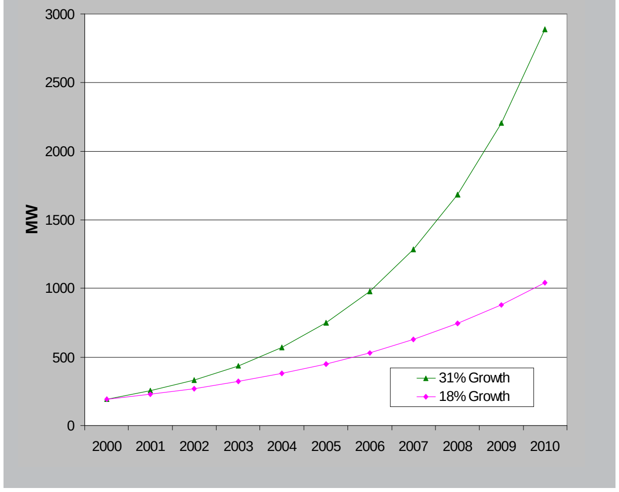


Figure 8: U.S. Solar PV Capacity Growth



nology develops, there will likely be opportunities to process hydrogen in the deserts for shipment elsewhere.

Solar power can generate electricity directly using photovoltaics (PV) as well. PV electricity production is all around us, from satellites to road signs to watches to rooftops. Total U.S. PV capacity of 194 MW is quite small compared to other energy sources, but growth of PV use has been steady and is expected to continue at an increasing rate. Both the domestic and worldwide growth rates for cumulative installed PV capacity have been increasing. The domestic PV capacity growth rate increased to 18.3% in 1999 from an average of 15.6% through most of the 1990s. Worldwide, the cumulative PV capacity growth rate increased from an average of 27% (1993-1999) to an average of 31% (1997-1999) and peaked at 37% in the last recorded year, 1999.[95]

If the cumulative U.S. PV capacity continues at the current domestic growth rate of 18%, it will increase from its current capacity of 194 MW to 1,000 MW by 2010.[96] If the U.S. strongly encourages the growth of solar energy, capacity could be added much more quickly. Growing at the 1997-99 worldwide rate of 31% annually, U.S. capacity could reach nearly 3,000 MW by 2010.

Geothermal Potential

The U.S. has tremendous geothermal resources. The DOE estimates high-temperature (electricity-generating quality) geothermal potential in the U.S. to be more than 4,000 quads (quadrillion Btus), more than forty times our current energy use.[97]

The last nationwide assessment of geothermal resources was published in 1978. It estimated a high-temperature potential of approximately 22,000 MW in nine western states (Alaska, Arizona, California, Hawaii, Idaho, Nevada, New Mexico, Oregon, and Utah) from known reserves. Estimates of undiscovered reserves ranged from 72,000 to 127,000 MW.[98] Since knowledge about geothermal resources has advanced dramatically since 1978, there is need for reassessment of these resources.

The DOE Office of Power Technologies' project entitled "Geopowering the West" has a goal for geothermal energy to provide 10%, or 10,000 MW, of the electricity needs of the western states by 2020.

The Energy Information Administration estimates the growth rate for geothermal capacity to be 7.2% through 2010.[99] Given this growth rate, U.S. geothermal capacity would reach over 5,600 MW by 2010, as shown in Table 4.

Table 4: Future Geothermal Generation with 7.2% Annual Growth

Year	New Installation	Total Capacity (MW)	Total Generation (GWh/yr)
2000		2,800	23,302
2001	202	3,002	24,979
2002	216	3,218	26,778
2003	232	3,450	28,706
2004	248	3,698	30,773
2005	266	3,964	32,988
2006	285	4,249	35,363
2007	306	4,555	37,910
2008	328	4,883	40,639
2009	352	5,235	43,565
2010	377	5,612	46,702

Energy Savings Potential

The U.S. could save energy and significantly reduce pollution by implementing effective policies encouraging energy efficiency. The American Council for an Energy-Efficient Economy (ACEEE) studied the impacts of several "smart energy" policies on U.S. primary energy consumption, economics, and emissions.[100] Under the "smart energy" policy scenario, the U.S. would reduce its total primary energy consumption by nearly 11% annually by 2010 compared to the business-as-usual, or base-case, scenario lacking new policies. Looking at the electricity production portion of this (90% of coal is used for electricity generation, 13% of natural gas, 100% of nuclear, hydro, and renewables), annual energy use for electricity would be reduced by 15% in the policy case by the year 2010 as compared to business as usual. A 15% reduction in electricity use in 2010 translates to more than 630,000 GWh saved and 700 million tons of carbon dioxide emissions avoided per year.

The set of policies analyzed in the study includes eight electricity-saving actions:

- Utility energy efficiency program to set aside funds for investment in energy efficiency.
- New and strengthened equipment efficiency standards.
- Tax incentives for energy-efficient homes, commercial buildings, and other products.
- Expanded federal energy efficiency research, development, and deployment programs.
- Promotion of clean, high-efficiency combined heat and power systems.
- Voluntary agreements and incentives to reduce industrial energy use.
- Improvements in efficiency and emissions from existing power plants.
- Greater adoption of current model building energy codes and development and implementation of more advanced codes.

Pollution Reduction Realized with Clean Energy Solutions

Tapping the renewable energy and energy efficiency potential ready for development now in Colorado and the nation would dramatically reduce power plant air pollution at both the state and national levels. By 2010, Colorado would reduce its CO_2 emissions by 15 million tons per year by developing clean energy solutions in place of coal, while the U.S. would reduce them by 11 billion tons per year.

Pollution Reduction in Colorado

As of 1998, Colorado's utilities were pumping an alarming 39 million tons of carbon dioxide, 98,000 tons of sulfur dioxide, 79,000 tons of nitrous oxides, and 470 pounds of mercury into the air annually, along with deadly particulate pollutants and a host of other toxins.[101]

As outlined above, Colorado could develop 13,000 GWh/yr of wind energy and save 5,000 GWh/yr through efficiency measures by 2010 with a reasonable amount of effort. Together, this is nearly 3,000 GWh/yr more than the 15,100 GWh/yr of projected demand growth. The state could thus cover all of its additional power needs with these clean sources and reduce the use of coal by the equivalent of one large power plant.

By developing these clean energy technologies, the state could reduce power plant pollution by approximately 10% by 2010. Comparing projections of annual power plant pollution in 2010, development of energy efficiency and renewables rather than further development of natural gas and coal would reduce pollution by 30%.

Three scenarios for Colorado yield much different pollution outputs:

Scenario One: Colorado adds all natural gas power plants to meet its growing electricity demand.

Scenario Two: Colorado adds a mixture of fossil fuels to meet its growing electricity demand (half coal & half natural gas).

Scenario Three: Colorado employs renewable energy and energy efficiency technologies to meet its growing electricity demand and replaces 3,300 GWh/yr of coal.

By developing clean power solutions (scenario three) rather than meeting electricity demand with gas- and coal-fired electricity, Colorado would avoid air pollution emissions of more than 15 million tons of CO_2, 32,000 tons of SO_2, 28,000 tons of NOx, and 150 pounds of mercury annually by 2010.

Table 5: Colorado Potential Clean Energy Development by 2010

	Capacity (MW)	Electricity Generation (GWh/yr)
1998 Use	6,937	35,500
2010 Projected Demand	9,900	50,600
Additional power needed by 2010	**2,300**	**15,100**
Potential Wind Energy Growth by 2010	5,000	13,000
Potential Energy Efficiency Development by 2010	1,000	5,000
Total Clean Energy Development by 2010	**6,000**	**18,000**

Table 6: CO Power Plant Pollution under Different Scenarios

Year	Scenario	Electricity Generation (GWh/yr)	CO2 Emissions (thousand tons)	SO2 Emissions (tons)	Nox Emissions (tons)	Mercury Emissions (pounds)
1998		35,471	39,107	98,324	79,225	473
2010	Scenario One	50,600	45,100	98,400	84,500	473
2010	Scenario Two	50,600	50,900	120,800	99,900	580
2010	Scenario Three	45,600	35,200	88,500	71,300	430

Table 7: U.S. Power Plant Emissions Comparison[103]

Year	Scenario	Electricity Generated or *Saved* (GWh/yr)	CO2 Emissions Generated or *Avoided* (thousand tons)	SO2 Emissions Generated or *Avoided* (thousand tons)	Nox Emissions Generated or *Avoided* (thousand tons)	Mercury Emissions Generated or *Avoided* (pounds)
2000	Current Generation	3,430,700	2,406,780	12,870	6,040	84,850
2010	Projected Generation	4,224,200	2,994,100	14,600	7,300	98,400
2010	**Projected Generation with Clean Energy Development:**	**3,590,600**	**1,880,100**	**8,000**	**4,400**	**54,300**
	Renewables Developable	359,250	*404,000*	*2,400*	*1,000*	*16,100*
	Energy Savings from Energy Efficiency	*630,000*	*710,000*	*4,200*	*1,900*	*28,000*
	Total Clean Energy Development		**1,114,000**	**6,600**	**2,900**	**44,100**

Pollution Reduction Nationwide

The U.S. potential growth of wind, geothermal, and solar power outlined above would generate 359,300 GWh/yr of electricity by 2010. This represents 8.4% of U.S. electricity demand projected by the EIA for 2010, not including current renewable energy generation and before any reductions in demand through energy efficiency measures are considered.

If these renewables were to replace coal power plants, CO_2 would be reduced by more than 400 million tons, SO_2 would be reduced by more than 2 million tons, NOx reduced by 1 million tons, and power plant mercury emissions would decrease by 16,000 pounds in the year 2010.

Energy efficiency measures resulting in a 15% reduction in electricity demand would eliminate the pollution associated with 630,000 GWh/yr of electricity production: 710 million tons of CO_2 emissions, 4 million tons of SO_2 emissions, 1.9 million tons of NOx emissions, and 28,000 pounds of mercury at the rate coal-fired plants emit pollution.

The combined impact of renewable energy and energy efficiency developed to replace coal-fired electricity generation would cut power plant CO_2 emissions by 37%, SO_2 emissions by 45%, NOx emissions by 40%, and mercury emissions by 45% by 2010 compared to projections for continuing on the current path.

Figure 9: CO_2 Emissions with Renewables and Energy Efficiency Replacing Coal

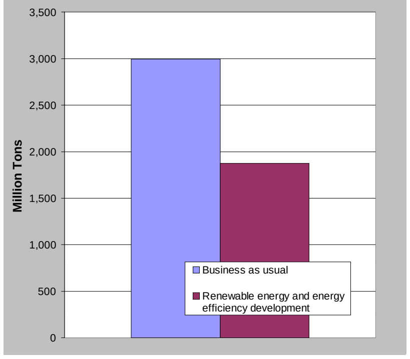


Figure 10: SO_2 Emissions with Renewables and Energy Efficiency Replacing Coal

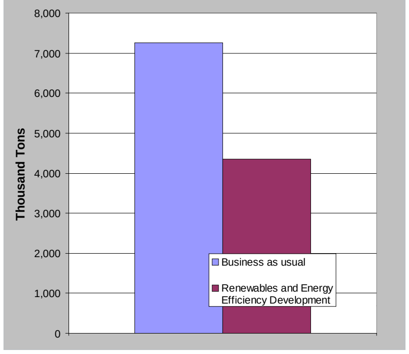
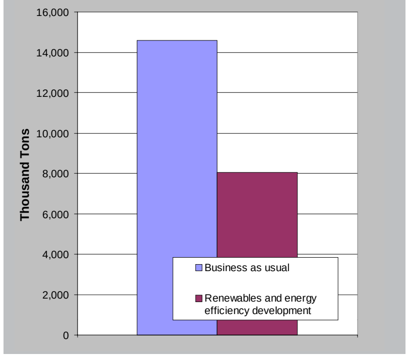


Figure 11: NOx Emissions with Renewables and Energy Efficiency Replacing Coal



Economic Feasibility of Clean Energy Solutions

Clean energy resources are economically viable today. Both energy efficiency measures and renewable energy technologies are more cost-effective in the long term than the current fossil fuel-dominated energy system. This was not the case a few decades ago when renewable energy resources were first presented as alternatives to oil and coal. But today any truly sound financial investment in the nation's energy future must involve aggressive and timely development of these resources.

- Energy efficiency measures have been proven on both local and national levels to be the best response to immediate power needs. They reduce pollution and energy demand at a cost that is less than that of most new power plants.
- Renewable energy technologies provide stable and declining electricity costs because their "fuel" is free in contrast to the volatility of fossil fuel prices. Renewable energy projects have the added economic benefit of creating more jobs than traditional fossil fuel electricity generation operations since renewable energy costs are more tied to skilled labor than to fuel.
- Clean energy solutions are even more attractive compared to fossil fuels when life-cycle environmental costs are accounted for.

Clean energy policies resulting in the increased use of both renewable energy and energy efficiency provide the best overall strategy for America's new energy future. Several recent studies examining the economic impact of efficiency and renewables stimulus programs found that the nation's economy would experience greater growth with policies encouraging renewables and energy efficiency than under a business-as-usual scenario.

Fossil fuel-generated electricity, on the other hand, is not a good long-term financial investment. Much of its costs are tied to limited fuel resources. Although the upfront capital costs of constructing a new fossil fuel power plant may be less than the upfront costs of a renewable energy power plant, the price of fossil fuel-generated electricity will forever carry a fuel cost. As changes occur in the supply and demand of the limited fuel, the cost will oscillate in response and eventually increase as the resource is depleted.

Fossil fuel-generated electricity also has significant life-cycle costs. Expenses related to the environmental and public health damages associated with fossil fuel extraction and power plant emissions do not appear on electricity bills, yet they are very real costs to society.

Although hydropower does not emit air pollutants, nearly all facilities have negative environmental impacts. This technology is not being considered as a significant source to meet growing electricity needs.

Nuclear power, the only other option for electricity generation, is prohibitively expensive, highly polluting, and unacceptably dangerous.

Energy-Efficient Technologies and their Costs

History has proven that adopting energy efficiency measures is the cheapest, as well as the easiest, quickest, and cleanest way to address urgent power needs. Nationally, utilities have saved 25,000 to 30,000 MW annually, the equivalent of 100 large power plants, over the past five years through energy efficiency programs. These programs averaged 2.8 ¢/kWh, a cost that is less than that of most new power plants.[104] In addition to cost savings, adoption of energy efficiency measures avoided the logistics and time involved with the siting of 100 large power plants, the acquisition of the rights of way for power lines and gas pipelines, and the emission of 190 million tons of CO_2.[105]

California is often considered a leader in energy efficiency efforts. Over the past twenty years, California has reduced its peak demand by 10,000 MW through utility energy efficiency programs and energy efficiency standards for buildings and appliances, yet there was still potential for increased savings.[106] In the face of its energy crisis last year, a concerted effort resulted in a reduction of electricity demand in the state by 6 percent from the same seven-month time period of a year ago, and a peak reduction of 12 percent over the previous year, while continuing to grow its economy. As a result, California avoided the National Electric Reliability Council's grim prediction of 250 hours of rolling blackouts this past summer that would have cut power to over 2 million households per blackout.[107]

Several recent studies have shown that the U.S. would continue to save energy and money in the future by implementing more energy efficiency programs and setting stricter efficiency standards.[108] The ACEEE study that determined the U.S. could reduce its electricity demand by 15% by 2010, for example, also revealed that a net savings of $152 billion dollars would accompany the energy savings by 2010 under their smart energy policy scenario.[109]

A variety of measures fall under the energy efficiency umbrella. Examples of utility energy efficiency measures include replacing older, less-efficient equipment with newer, more-efficient equipment. This equipment can include:

- High-efficiency pumps and motor retrofits for large oil and gas producers and pipelines.
- Redesigned electricity generators with combined heat and power systems that recycle and reuse waste heat, which significantly increases their efficiency.
- Smaller onsite efficient electricity generators (rather than large central power plants) that match the power needs of the district or building and bypass the need for long-distance transmission of electricity where significant losses of energy occur.

Examples of consumer energy efficiency measures include:

- Weatherizing homes.
- Replacing old appliances with newer, more efficient ones.
- Installing electricity, heat and air-conditioning systems that are responsive to real-time energy demands, shifting energy consumption to off-peak times when necessary.

Renewable Energy Technologies and their Costs

Because renewable energy has no fuel costs, its total costs are predictable and stable. Once the plants are built, producers only have to pay the regular operating and maintenance costs to keep the power flowing. The fluctuating fuel costs of fossil fuel-based power plants are not a factor for renewable energy producers.

The fact that more of the costs are upfront rather than spread out in the form of ongoing fuel costs constitutes a challenge in the development of renewable energy projects, since investors need to undertake more financing at the start of the project. However, since this also results in greater certainty of the total costs over the full lifetime of the plants, hesitation over high initial investments can be eased through market certainty. When a state enters into long-term contracts with renewable producers, guaranteeing a stable price for much of the lifetimes of their plants, the initial investment hurdle is greatly reduced.

The combination of advanced technology and market growth in renewable energy industries over the past decades has lowered costs markedly. The average prices of wind and solar energy have plummeted over the last twenty years and are predicted to continue to decline. Geothermal energy costs, which currently range from slightly higher to lower than conventional fossil fuel power, have also declined historically and are predicted to remain roughly the same over the next ten years.

Wind

The cost of producing electricity from wind energy has declined by more than 80% in the past twenty years, from about 38 cents per kilowatt-hour (¢/kWh) in the early 1980s to a current range of 3 to 8 ¢/kWh (levelized over a plant's lifetime). This does not include the federal wind energy Production Tax Credit, which reduces the cost of wind-generated electricity production by about 0.7 ¢/kWh over the lifetime of the plant.

The cost of electricity from wind plants varies based on their size and the average wind speed. A large plant (50 MW and up) at an excellent site (20 mph average) can deliver power for 3 ¢/kWh or less. Electricity from a small plant (3 MW) at a moderate site (16 mph) may cost up to 8 ¢/kWh, which is still lower than retail cost in many areas. Analysts believe that wind energy costs could fall to 2.5 ¢/kWh in the near future, making wind power more competitive than most conventional energy sources.[110]

Solar

Solar Thermal Power Plants

The first Solar Electricity Generating System (SEGS) plant was installed in California's Mojave Desert in 1984 and generated electricity for 25 ¢/kWh (1999 dollars). The California SEGS plants now have a collective capacity of 354 MW and generate electricity for 8-10 ¢/kWh. A new solar thermal plant with a capacity of 100 MW or more installed today could generate electricity for 7 ¢/kWh.[111]

Solar energy has the unique advantage of peaking when the electricity grid experiences some of its highest demands – in the heat of summer afternoons. In contrast, when traditional fossil fuel plants attempt to address peak needs, they often must operate for far longer periods than the true peak load period due to long start-up and shut-down procedures. The wasted fuel and added pollution increases the cost of generating electricity during peak times. For this reason, solar power plants are cost-competitive in the peak power market today.

Photovoltaics

PV can generate electricity for 12-25 ¢/kWh today.[112] This is more economical than fossil fuel-generated electricity right now for some situations, such as remote applications in the U.S. and vast areas of the developing world that have no grid/power plant infrastructure in place. However, without subsidies, it is not competitive with the lowest rates from gas- and coal-fired power plants today in the grid-connected developed world.

An important consideration in cost comparisons of traditional power plants and PV is that when a PV system is installed in a home or business, there are no mark-up costs to middlemen and no distribution costs. Therefore, the comparisons must take place at the retail cost of electricity rather than the wholesale cost of the fuel or the power plant generating cost. The average U.S. residential retail cost of electricity is 8.5 ¢/kWh, though it can cost over 14 ¢/kWh in some states.[113] In 1996, the cost of installing a PV system represented either no net cost or profit over remaining completely dependent on grid-connected power in only five states. Just three years later, this was true in fifteen states.[114] Residential rates, along with tax credits and/or capital cost reduction policies, were the most influential factors rendering PV cost-effective in these states.

Economies of Scale

Although technological breakthroughs may lower PV prices significantly, the biggest price reductions are expected from economies of scale due to increased PV panel manufacturing volume.

The current cost of PV modules is quoted at about $3.50-$3.75 per watt wholesale and $6-$7 per watt for an installed system.[115] This is a dramatic reduction in cost from $20 per watt ten years ago and a hundred-fold drop

Table 8: Experience Curve for PV Module Price

Doubling	Installed MW	Wholesale Price per Watt	Installed System Price per Watt
0	1,034	$3.50	$6.50
1	2,068	$2.87	$5.33
2	4,136	$2.35	$4.37
3	8,272	$1.93	$3.58
4	16,544	$1.58	$2.93
5	33,088	$1.30	$2.40
6	66,176	$1.06	$1.97
7	132,352	$0.87	$1.62
8	264,704	$0.72	$1.32
9	529,408	$0.59	$1.08
10	1,058,816	$0.48	$0.89

in cost since 1972.[116] The cost will continue to decline as PV manufacturers reach economies of scale. Since nearly all of the costs for PV-generated electricity lie in the equipment, the more equipment manufactured on a mass scale, the cheaper the electricity becomes.

The relationship between increased volume and decreased price is called the experience curve. For PV, it is estimated to be 82%. That is, for every doubling of cumulative production volume, the price of PV is expected to decline by 18%.[117]

In 1999, total worldwide installed PV capacity was 1,034 MW.[118] The next three doublings of this amount will each reduce the price of installed systems by about one dollar per watt.

To compete on equal footing with traditional power sources in a short-term economic view, PV prices will need to be around $1/watt for an installed system.[119] According to this experience curve, that price will be reached once total PV installations surpass 500,000 MW.

The PV industry clearly has a fair distance to go, but it is steadily progressing toward its goal. PV module shipments in the U.S.

Figure 12: Annual PV Manufacturing Volume[121]

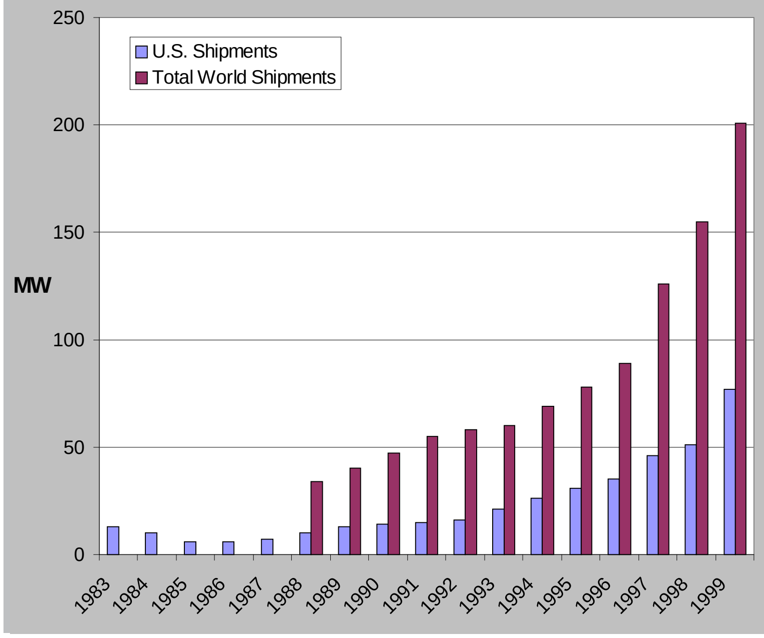
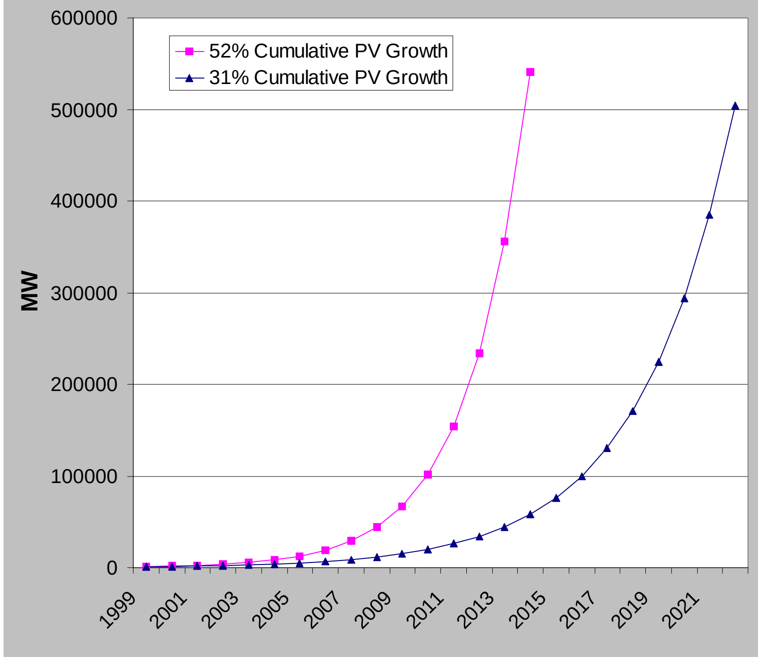


Figure 13: PV Market Growth Rates[122]



and worldwide have steadily increased over the past twenty years. Furthermore, the rate by which shipments have increased has risen.

From 1989-99, the growth rate of worldwide PV modules manufactured averaged

18%. For the same time period, the growth rate for U.S. manufacturers was 21%. Recently the growth rate has been much higher. The average growth rate in 1997-99 in the U.S. and worldwide was 31%. In 1999, the U.S. growth rate of PV modules manufactured was 52%, the highest ever, while the worldwide growth rate of shipments remained at a healthy 30%.[120]

If the growth rate in PV manufacturing activity continues at the 52% level it reached in the U.S. in the past year, cumulative worldwide PV capacity will have reached 500,000 MW by 2013. If growth in manufacturing only grows at the 1997-99 average rate of 31%, the industry will have reached this milestone in 2022.

Geothermal

Geothermal energy provides the U.S. with 2,700 MW of capacity. Currently geothermal fields are generating electricity for 1.5-8 ¢/kWh.[123]

The Geysers in California are a good example of how renewable energy, with the bulk of its costs upfront, can provide electricity at stable and declining costs. The plants were built in the 1960s and are still operating today with much of the original infrastructure, including the wells. Since the capital costs of the original construction have been paid off and the resource continues to fuel the plant at no cost, the only expenses are ongoing operation and maintenance costs. The plants are now producing electricity for 3 ¢/kWh.[124]

Biomass

A power plant burning 100% biomass can produce electricity for about 9 ¢/kWh, though advances in technology are expected to bring the cost down to 5 ¢/kWh in the future.[125] A more common practice today is to co-fire biomass materials with coal (burning a mixture of biomass materials with coal to drive the electric generator). Co-firing with inexpensive biomass can reduce the cost of coal-generated electricity from about 2.3 ¢/kWh (not considering external life cycle costs) to 2.1 ¢/kWh, but clearly this practice cannot be considered a clean energy solution.

Economic Benefits of Combining Energy Efficiency and Renewable Energy Resources

The 1997 Kyoto protocol, an international treaty to reduce global-warming greenhouse gases, prompted analyses of the feasibility and impacts of carbon reduction strategies in the U.S. Given that power plants account for 40% of U.S. carbon dioxide emissions, power plants were featured prominently in these strategies. Each of these reports produced concurring results:

- A 1997 study by five national laboratories concluded that a vigorous national commitment to developing and deploying energy-efficient, low-carbon, and renewable technologies can reduce pollution, reduce energy consumption and produce energy savings that equal or exceed the costs of the endeavor.[126]
- Another 1997 study by five environmental and public policy organizations found that policies encouraging energy efficiency, renewable energy, and other advanced clean technologies would result in lower energy consumption, lower CO_2 emissions, billions of dollars in consumer energy bill savings, and a net employment boost of nearly 800,000 jobs in the U.S. by 2010.[127]
- In 1998, the U.S. Environmental Protection Agency analyzed policy and program scenarios with help from the Lawrence Berkeley National Laboratory. The analysis identified a relationship between carbon emissions mitigation (through development of energy-efficient, low-carbon, and renewable technologies) and economic activity wherein carbon mitigation resulted in increased gross domestic prod-

uct and economic savings by 2010 and beyond relative to business-as-usual projections.[128]

- In 2000, the Interlaboratory Working Group on Energy-Efficient and Clean Energy Technologies examined the potential for public policies and programs to address current energy-related challenges. Their study concluded that public policies promoting energy efficiency and clean energy production can significantly reduce power plant air pollution with economic benefits that are comparable to overall program implementation costs.[129]

All of these studies address the problem of pollution with a comprehensive and long-term approach, and all of these studies disprove the long-held misconception that we must choose between cleaner energy production and economic growth. Their solutions are similar in that each multifaceted scenario involves using energy more efficiently and diversifying our energy mix by adding clean renewable technologies to our portfolio.

Since we currently use heavily polluting sources of energy to generate our electricity, energy efficiency measures will have the greatest effect on reducing pollution in the near term by simply reducing the amount of energy needed. Since we will always need electricity, renewables will enable us to develop a sustainable system for utilizing energy with minimal pollution in the long term.

Conventional Sources of Electricity Generation and their Costs

Coal, natural gas, and nuclear power serve as the major sources for America's electricity generation. Current trends are pointing us in the direction of increased dependence on these unsustainable resources. A closer look into to the life cycles of each of these resources reveals why they are unsustainable and more costly than clean energy solutions in the long term.

Fossil Fuels

Fossil fuels are a limited resource. Clearly we cannot continue to rely on them forever. Some people fear that we will run out and have no place to go, while others feel that we will keep finding new deposits and do not need to worry about it. Both of these views miss the point. We should be concerned about the limited nature of fossil fuels because of escalating environmental costs, volatile fuel costs and supply instabilities, and because deepening our dependence on them is money and effort poorly spent when we will unavoidably need to transition to renewable fuels.

Natural Gas

Natural gas is currently the world's favored fossil fuel because it is the cleanest burning fossil fuel. Energy companies have responded to concerns about the health and global warming effects of burning coal by proposing that nearly all future electricity-generating power plants be fueled by cleaner-burning natural gas.

Because its emissions are cleaner and because we are not yet geared up to rely completely on sustainable fuels, gas is extremely valuable and should be treated as a precious, limited, transitional resource to aid us as we shift our reliance onto sustainable energy sources. Instead it is being regarded as an unlimited commodity whose availability will be appropriately managed by market forces alone.

Market forces would eventually treat natural gas as a limited resource, but this would happen very slowly and only after wasting unnecessary amounts. Most energy experts agree that the average price of natural gas will gradually rise over the coming years and decades. Even the unflinchingly optimistic Energy Information Administration (EIA) predicts that natural gas prices will rise between 1.2% and 2.8% per year in constant dollars through 2020.[130] Energy experts of all backgrounds agree that energy production will shift from natural gas and other fos-

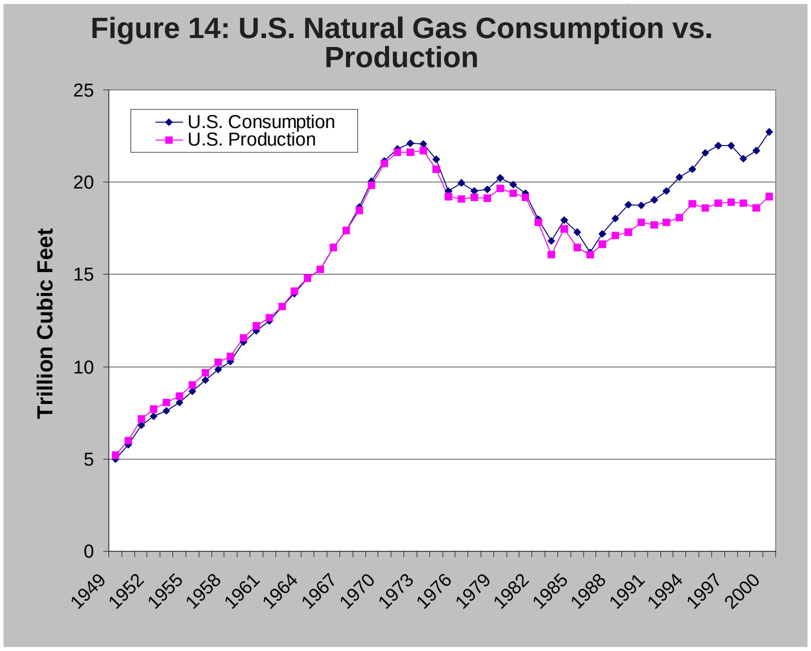


Figure 14: U.S. Natural Gas Consumption vs. Production

sil fuels to renewable technologies as the price of fossil fuels goes up and the price of renewables declines. To make this shift before supplies are squandered too extensively and to correct for historical manipulations of the market favoring fossil fuels, renewable energy development should be encouraged now.

Natural gas prices are also subject to dramatic volatility, as was clearly seen in the "energy crisis" in California over the past year. According to the Department of Energy, the cost of generating electricity using natural gas was 3.7 ¢/kWh in 2000, but the cost reached as high as 43 ¢/kWh in February 2001 in California.[131] In 2001, the cost of natural gas in Colorado was 5 ¢/kWh.[132]

The price of fossil fuel-generated electricity is dominated by the ongoing cost of the fuel. Several factors directly affect the cost of fossil fuels:

- Supply and demand.
- Accessibility of reserves.
- Infrastructure requirements for transportation and distribution.

Supply and Demand

The U.S. does not have enough domestic reserves of natural gas to satisfy our growing demand. The U.S. Geological Survey estimates that the U.S. has 1,049 trillion cubic feet of gas remaining, of which only 16% are proved reserves. If demand were to grow by 2.3% through 2020 as predicted by the Department of Energy and stay constant thereafter, and imports from foreign nations remain around 16% of demand, this amount of gas only constitutes a 38-year supply. We will therefore have to rely increasingly on expensive and unstable foreign shipments of natural gas.

Since 1986 the U.S. has not produced enough natural gas to meet its demand, and the gap continues to widen.[133]

Accessibility

Many of the new gas wells needed in the next twenty years will be tapping reserves that are more difficult to reach than those we've already tapped. As the Energy Information Administration has stated in explanation of its forecast of increasing natural gas prices, "increases reflect the rising demand projected for natural gas and its expected impact on the natural progression of the discovery process from larger and more profitable fields to smaller, less economical ones."[134]

Energy companies have had to drill a vastly increasing number of wells each year to provide a marginally increasing supply of gas. If they are to increase production dramatically over the next twenty years as projected, they will have to increase drilling far beyond current and previous rates. Due to declining well productivity, meeting those projections may not even be possible.

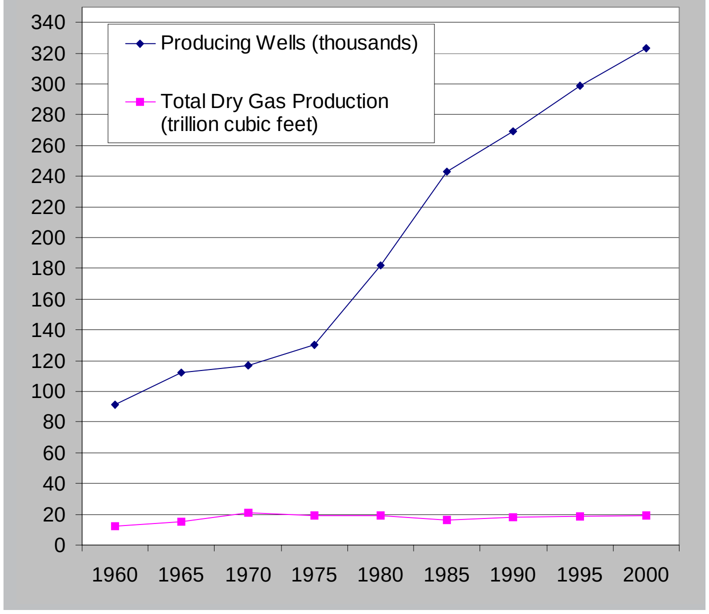
Well Productivity

The productivity of gas wells peaked in 1973 and has steadily declined since then. The 124,000 wells in the U.S. in 1973 produced an average of 182 million cubic feet (MMcf) of natural gas. This productivity fell sharply in the following years, then continued on a gradual decline. From 1984-2000, the average annual gas production per well declined by 21 percent. In 1999, the country had two and a half times as many wells as in 1973, but each well was producing less than a third as much gas – 307,000 wells produced an average of 55 MMcf/yr each.

The natural gas industry has evidence that the rate per well of natural gas production will continue to decline. William Wise, Chairman and CEO of the world's biggest natural gas company, El Paso Corp., recently stated plainly that gas production in North America is flat despite a recent surge in drilling. Receipts from his company's expansive pipeline systems have stayed roughly constant for the past three years. "Our field services are in all of the basins where all of the drilling in the United States is taking place and we are not seeing a production response. We're just kind of treading water, holding our own," Wise told an annual energy conference in March 2001. Decline rates – the reduction in well output over the previous year – have increased from 17% per year in 1970 to nearly 50% today. "What not everybody realizes is the same thing is happening in Canada," Wise said. Decline rates there went from 20% per year in 1990 to 40% per year in 1998.[135]

If the productivity per well stays constant at the current rate of 55 MMcf/yr, 529,000 producing wells will be needed to meet the U.S. projected demand of 29.1 tcf of gas in 2020. This is 72% more than the 307,000 wells in operation in 1999. With the generous assumption that all current wells will still be producing gas in twenty years, the U.S. would need an additional 221,600 producing wells. Since only one out of two wells drilled actually produces gas, 443,200 wells would need to be drilled, an average of 23,300 per year. This is just slightly more than the number of wells that were actually drilled in 2000.[136]

Figure 15: U.S. Producing Wells vs. Total Dry Gas Production



However, since the productivity per well has declined continually since 1973, it would be more realistic to assume that the productivity rate will continue to decline. Between 1984 and 2000, productivity declined by 21%. If productivity declines another 20% over the next twenty years, 707,800 new wells will need to be drilled, an average of 37,000 per year. Since drilling will be significantly less than that in the next few years as the industry gradually expands, drilling in the latter part of the twenty-year period will need to be well over 40,000 wells per year, a truly unprecedented amount.

Imports

Since domestic supplies are limited, if we continue to increase our dependence on natural gas, we will have to turn to expensive overseas shipments.

Gas imported from Canada can be shipped by pipeline, but as Canada experiences declining production rates like the U.S., we will be forced to look to other continents for imports. To import natural gas from overseas, the gas must first be turned into a liquid by cooling it to -256 degrees Fahrenheit. It is then shipped in tankers, turned back into a gas at receiving facilities, and sent by pipeline to its final destination. The process will certainly increase natural gas prices.

Infrastructure

The U.S. gas pipeline and electricity power line network is in desperate need of attention. In most parts of the country, the network is operating at its upper limits. New infrastructure needed to feed the multitudes of new gas plants planned for the U.S. will affect the cost of natural gas.

Vice President Cheney has called for the construction of more than one power plant per week for the next twenty years, with most of them fueled by natural gas. He recently stated that the Bush energy plan would require 38,000 miles of new gas pipelines.[137] At a rough estimate of $700,000 to build a mile-long stretch of pipeline in an unpopulated area and $2 million per mile in populated areas, this one piece of the Vice President's plan would cost $27 - $76 billion.[138] Along with the cost of finding and extracting natural gas, this will be a tremendous investment for a relatively short-term solution.

At an average power plant lifetime of forty years, domestic production of natural gas will peak well before those plants are used for their full lifetimes. In recent years, "stranded costs" from bad investments in nuclear power plants have been an issue. Twenty-five years from now, we may face stranded costs from gas-fired power plants that are no longer economically viable due to limited resources.

Coal

Coal is used for electricity generation in the U.S. more than any other resource for two basic reasons: it is a domestic resource and, by ignoring life cycle costs, coal appears to be the cheapest of all energy resources.

As downstream effects of burning coal are being recognized, studies have begun to reveal the truer costs of coal-burning power plants. Without life-cycle costs included, coal-fired electricity generation costs about 2.3 ¢/kWh.[139] When external costs are accounted for, the cost rises to more than 8 ¢/kWh.[140] This is more expensive than many emission-free renewable energy projects.

Fossil Fuel/Renewable Energy Cost Comparison

When the true costs of the life cycles of "cheap" fossil fuels are revealed, renewable technologies often prove to be less expensive. In 1994, the U.S. Office of Technology Assessment reviewed previous studies of the environmental costs of electricity production. The studies mostly measure the costs of compliance with air quality regulations, transportation costs associated with energy production, land use impacts, and some public health costs. Only one study, the more recent analysis by the European Union and the U.S. Department of Energy published in 2001, attempted a comprehensive set of costs including the costs of climate change, human death and illness from disease and accidents, reduced production of crops and fisheries, degraded structures, lost recreational and tourism opportunities, degraded visibility, loss of habitat and biodiversity, and use of land, water, and minerals. The other studies each contain some subset of these impacts.

2001 costs for renewables in this table are the national average of today's range of costs for each resource. Solar PV costs must be compared to retail electricity costs, which range from 5-14.8 ¢/kWh for residential rates.[143]

Coal has the greatest external costs. Natural gas, though its air emissions are cleaner than coal, also has significant external costs due to its environmental impacts. Once some external costs are included in the generation costs, renewable energy sources are far more

Table 9: Studies of External Costs of Electricity Generation (¢/kWh, 2001 dollars)[141]

Study	Coal	Combined Cycle Natural Gas	Solar PV	Wind	Geothermal	Biomass
1990 Pace University	3.91-9.58	1.5	0.0-0.5	0.0-0.1		0.0-0.9
1991 Tellus Institute	6.03-13.45	2.27				
1989 PLC Consulting	4.7-8.4	2.8				
1999 Fraunhofer Institute			0.4	0.009		
1986 Bonneville Power					0.0-0.029	
1982 NRDC	4.05-6.75			0.0-0.27		
2001 U.S. DOE/European Union	5.8	1.8	0.6	0.15		1.1
Average	**6.6**	**2.1**	**0.4**	**0.09**	**0.01**	**0.8**

competitive, with costs of some renewables less than that of fossil fuels. In Colorado, wind power can generate electricity for 3 to 3.5 ¢/kWh, which is cheaper than natural gas-generated electricity at 5 ¢/kWh even without considering external costs.[144]

Nuclear Power

Nuclear power is not the answer to cleaning up our electric power industry-related pollution. It is not cheap and it is not safe.

Nuclear power would not exist in this country today were it not for enormous subsidies paid for by taxpayers and ratepayers. Taxpayer-financed federal R&D money alone has totaled $66 billion.[145] On top of that, the nuclear industry has received a special taxpayer-backed insurance policy known as the Price Anderson Act, taxpayer-funded cleanup of uranium enrichment sites, the costly privatization of the previously government-owned Uranium Enrichment Corporation, and unjustifiably high electricity rates from state regulators. Add to this the enormous bailouts in state deregulation plans that began a few years ago and will continue in the coming years. "Stranded costs" in just eleven key states may total more than $132 billion.[146]

Table 10: Electricity Generating Costs with Some External Costs (¢/kWh)[142]

	Coal	Natural Gas	Solar PV	Wind	Geothermal	Biomass
Basic Generating Cost	2.3	3.9	18.5	5.5	4.8	9
External Costs	6.6	2.1	0.4	0.09	0.01	0.8
2001 Cost	**8.9**	**6**	**18.9**	**5.6**	**4.8**	**9.8**

Job Gains from Clean Energy Solutions

A clean energy strategy involving renewable energy projects and energy efficiency measures would provide a net increase in jobs for Americans. Both renewable energy and energy efficiency projects would employ people for manufacturing, installing, and servicing equipment.

While much of the generating costs of electricity production from fossil fuels goes to fuel, electricity generation from renewable energy involves a higher proportion of its costs for skilled labor. A recent report by the Renewable Energy Policy Project (REPP) estimated labor requirements for coal, wind, solar PV, and biomass co-firing. According to REPP, wind and solar PV would provide 40% more jobs per dollar of cost (including capital, construction, and generating costs), compared to coal employment.[147]

According to their analysis, a 37.5 MW wind project would require 9,500 hours of labor per megawatt of power installed and operating for one year. This translates to 4 person-years per megawatt, meaning four people could be employed for one year or one person for four years, assuming a 10-year operation period. The operations involved in producing electricity from a 2 kW solar PV system would require 35.5 person-years per megawatt of power output.

The California Energy Commission (CEC) conducted its own analysis of job impacts associated with different electricity generating technologies. Unlike the REPP analysis, the CEC separated temporary construction jobs from long-term operating employment.

The CEC analysis also found that renewable energy technologies employ far more people than natural gas power plants. Comparing jobs created by a new 300 MW power plant operating for 30 years, renewable energy technologies create at least 5 times as many jobs as new combined cycle plants (for solar PV) and as much as 25 times as many jobs (for geothermal).

Net Job Gains in Colorado

Colorado would experience a net job gain with renewables and energy efficiency development even after considering the employment losses in the conventional fossil fuel industry.

A study conducted by the Tellus Institute found that implementing climate protection policies would result in net job gains across the country. The suite of policies in the climate protection scenario included policies addressing the buildings and industry sector and the transportation sector along with a renewable portfolio standard and caps on CO_2, SO_2, and NOx emissions to directly address the electricity sector. Under this climate protection policy scenario, the study estimated Colorado would see a net job gain of 10,000 jobs.[149]

Another study, by Economic Research Associates, concurred. *Colorado's Energy Future: Energy Efficiency and Renewable Energy Technologies as an Economic Development Strategy* concluded that a net gain of 8,400 jobs would result from the development of energy efficiency and renewable energy technology industries.[150]

Table 11: Job Impacts of Electricity Generating Technologies[148]

Resource	Construction Employment (jobs/MW)	Operating Employment (jobs/MW)	Jobs Created per 300 MW Plant	Factor Increase in Jobs over Combined Cycle Plants
New Combined Cycle Natural Gas Plants	0.60	0.04	630	1
Wind	2.57	0.29	3,381	5.4
Solar PV	7.14	0.12	3,222	5.1
Solar Thermal	5.71	0.22	3,693	5.9
Geothermal	4.00	1.67	16,230	25.8

Net Job Gains Nationwide

The National Center for Photovoltaics estimates that the PV industry alone currently employs some 20,000 American workers in high-value, high-tech jobs. By 2020, the industry expects the workforce to reach 150,000. Several years beyond 2020, the PV industry estimates it will double this employment level, with jobs at the same level currently supported by General Motors or the U.S. steel industry.[151]

Even considering the job losses that would occur in the fossil fuel energy industry, the Tellus Institute study mentioned above found that a net gain of more than 700,000 jobs in the U.S. would be created by 2010 under their climate protection scenario.[152] Although the number of jobs gained varies from state to state, all states would see a net gain in the number of jobs, even those that produce significant amounts of fossil fuels, like Texas.

POLICY RECOMMENDATIONS

A comprehensive energy policy on a local, state, or national level must address four major priorities:

1) Energy conservation and efficiency.

2) Promotion of clean, renewable energy sources.

3) An end to wasteful subsidies for fuels and technologies that are neither clean nor sustainable.

4) Promotion of more local control and democratic governance over energy.

State Policy Recommendations

With energy policies that address these four areas, Colorado can begin cost-effectively phasing out dirty coal power plants, replacing them with cleaner and more sustainable resources, and reducing overall demand through energy efficiency strategies. The benefits of such a transition include a dramatic reduction in pollution, a more reliable energy system, and a stronger, more stable economy for the state.

1) Policies Promoting Energy Conservation and Efficiency

Colorado has several energy efficiency programs in place at the city level that vary across the state. These programs encourage energy efficiency through construction and design standards and equipment certification. These policies should be replicated in other communities throughout the state.

- Renewable Energy Mitigation Program – Aspen (construction/design standard)
- Green Points Building Program – Boulder (construction/design standard)
- Construction & Design – Denver (construction/design standard)
- Equipment Certification – Aspen, Boulder (equipment certification)

Statewide, Colorado should implement policies that have been proven effective elsewhere:

Utility Energy Efficiency Program:

A Utility Energy Efficiency Program (often referred to as a public or systems benefits charge) establishes a uniform charge issued by the electric utilities to all customers. The revenues received are set aside for a wide range of energy efficiency and renewable energy programs. This has proven to be very successful in other states, saving money, reducing electricity demand, and reducing pollution.

State Tax Incentives:

Taxation has long been a proven method for encouraging or discouraging targeted business practices. Tax incentives should be set for energy efficiency measures to encourage individuals and businesses to incorporate energy efficiency improvements and technologies.

State Agency Requirement for Energy Efficiency Investment

State-owned buildings should be constructed or retrofitted with high efficiency lighting, heating, venting, air conditioning, and appliances in order to reduce energy consumption and to support energy efficiency technology and businesses in Colorado.

State Adoption of the International Energy Efficiency Code:

Energy codes provide builders with minimum standards for energy efficiency in buildings. An absence of minimum standards discourages builders from incorporating energy efficiency measures. Unfortunately, Colorado does not have a meaningful statewide efficiency building code.

Currently, municipalities determine whether to adopt efficiency codes, and how stringent the codes are. Many cities use the hopelessly outdated Colorado State Code, which was created in 1977, well before today's levels of efficiency technology. Other municipalities have realized significant energy savings by adopting more aggressive codes like the International Energy Efficiency Code (IEEC). Fort Collins, for example, adopted the IEEC and reduced its electricity demand by 16%. If Colorado were to adopt the IEEC across the entire state and realize a statewide reduction in electricity demand of 16%, 1,100 MW of energy would be saved. That is the equivalent of nearly two large coal-fired power plants, and would reduce CO_2 pollution by about 9 million tons annually.

The IEEC was originally developed jointly under the auspices of the Council of American Building Officials, Building Officials and Code Administrators International, Inc., International Conference of Building Officials, National Conference of States on Building Codes and Standards, and Southern Building Code Congress International under a contract funded by the U.S. Department of Energy.

2) Policies Promoting Clean, Renewable Energy

Across Colorado there are several utility- and city-based green purchasing and renewable energy-promoting programs currently in place:

- Green Power Program – Colorado Springs
- Wind Power Program – Estes Park, Fort Collins
- Wind Power Pioneers – Holy Cross Electric
- Wind Program – Longmont
- Wind Energy Program – Loveland
- SolarSource – Public Service Company of Colorado
- WindSource - Public Service Company of Colorado
- Renewable Energy Trust – Individual Utilities
- Green Power Purchasing – Aspen, Boulder, Denver
- PV Contractor Licensing & Inspection – Aspen (contractor licensing)
- Line Extension and Photovoltaic Cost Evaluation – State (economic analysis)
- Solar Access Ordinance – Boulder (solar access law)
- Executive Order for the Use of Renewable Energy by State Agencies – State (state construction policy)
- Net Metering – Utility-based (renewable energy interconnection rule)

These programs are an excellent start for a comprehensive energy policy for the state, but Colorado also needs to add some essential statewide policies in order to realize its renewable energy potential:

Renewable Portfolio Standard (RPS):

A renewable portfolio standard would require all retail electricity suppliers to include a percentage of renewable resources in their generation mix. Colorado should enact a standard calling for its energy mix to include 10% renewables by 2010 and 20% by 2020.

Utility Renewable Energy Development Program:

This program is identical to the Utility Energy Efficiency Program, with revenues set aside for a wide range of renewable energy programs.

State Agency Requirement for Renewable Energy Purchases:

The state could have a significant effect on the renewable energy industry by requiring its agencies to purchase 10% of their power from renewable sources. This would provide a dependable market for local renewable energy companies as well as reducing pollution and helping to stabilize utility prices.

Net Metering:

For those electric utility customers with their own on-site electricity generating systems, net metering allows electricity to flow both to and from the customer. When excess electricity is generated by the customer's own system, the excess is fed back into the grid and the customer is compensated for it.

Wind and solar power, two popular on-site generating systems, produce electricity intermittently according to the availability of their sources. Often they generate more power during peak times than the immediate site requires. Net metering allows more efficient use of electricity by capturing all electricity generated from these on-site systems and distributing it to other users. In turn, the centralized power plant provides electricity to net-metering customers during times when the sun is not shining or the wind is not blowing.

Since 1994, some individual utilities in Colorado have offered net metering for grid-connected renewable energy systems. Individual systems are limited to 10 kW.

The Public Utilities Commission should expand net metering statewide and increase the limit per system from 10 kW to 1 MW. Increasing the limit would encourage businesses with greater demand to invest in more efficient on-site electricity generation systems.

State Tax Incentives for Renewable Energy:

Tax incentives for the purchase and installation of on-site renewable energy technologies helps even the playing field for renewable technologies as they compete with traditional sources of energy for electricity generation. Since nearly all of the costs of renewable energy technologies are upfront rather than spread out in the form of ongoing fuel costs, tax incentives for these upfront costs are one way to help individuals and businesses handle the challenge of the upfront investment.

Taxing central station energy producers on power output rather than capital assets is another way to level the playing field between renewable and traditional energy sources. Currently energy producers are taxed on their capital assets rather than their power output. This gives an advantage to traditional power producers, since renewable power producers invest more in capital rather than fuel.

Land Leasing Policy for Renewable Energy Producers:

The state of Colorado owns some three million acres of land, much of which is located in prime potential wind farm areas in the eastern plains. The land is already used for agriculture and mining purposes. Wind turbines typically only use about 5% of the land set aside for a wind farm, so they are compatible with, and often located on, farmland and ranches.

3) Policies Ending Wasteful Subsidies for Fuels and Technologies that Are Neither Clean Nor Sustainable

Colorado should not subsidize coal and gas production, both of which cost us dearly in environmental and public health consequences. In Colorado in particular, where renewable energy potential is so great, subsidies to polluting energy sources are a waste of money.

4) Policies Promoting More Local Control and Democratic Governance Over Energy

In a democratic society, public preferences must be represented during the process of energy policy development. Currently the voices of Coloradans are not being considered as choices for energy development with long-lasting consequences are being made. The majority of Colorado homeowners prefer solar energy and wind power to conventional sources, yet only one wind project has been approved along with a multitude of fossil fuel projects in the last integrated resource plan evaluation by the Colorado Public Utilities Commission.

Deliberative Polling

Deliberative polling combines formal consultation in small group discussions with scientific random sampling to incorporate public opinion in the decision-making process for public policy. Deliberative polling has been used in Texas, which is now a leader in renewable energy and energy efficiency policy. The Colorado Public Utilities Commission should use deliberative polls in its integrated resource planning process.

Federal Policy Recommendations

Just as on the state level, a clean energy policy on the national level must include policies that address the same major areas. The two most important policies needed on a federal level to achieve the goal of a clean and sustainable energy future for America are a Renewable Portfolio Standard (RPS) and a Utility Energy Efficiency and Renewable Energy Development Program (Public Benefits Fund).

Renewable Portfolio Standard

A renewable portfolio standard, as described above in the state policy recommendation section, should also be implemented on the federal level. The potential power output of wind, solar, and geothermal resources in the U.S. is many times greater than our total electricity consumption. A national renewable standard requiring all retail electricity suppliers to include 20% of renewable resources in their generation mix by 2020 would benefit the country's economy and environment.

Utility Energy Efficiency and Renewable Energy Development Program

As described under the state policy recommendation section, the revenues received from the uniform utility charge are set aside for a wide range of energy efficiency and renewable energy programs. On the federal level, however, revenues collected would be distributed by matching funds collected by individual state utility energy efficiency and renewable energy development programs.

In addition to these priorities, other federal measures should be continued or created to ensure a viable national energy policy.

Incentives for Energy-Efficient Products, Buildings, and Power Systems

Efficient use of energy is critical to a sustainable energy system. Multiple incentives targeted at different consumers and uses should:

- Provide consumers with energy efficiency incentives such as rebates for energy-efficient home appliances and construction.
- Provide incentives to industrial users of power to become more energy-efficient.
- Require real-time pricing structures for large industrial power users.
- Provide incentives to power plants that adopt combined heat and power systems to use waste heat and increase efficiency.

Efficiency Standards and Building Codes

Efficiency standards and building construction codes need to be updated in order to take advantage of technology advancements. Aggressive but achievable standards should be established for the construction industry and for appliances, transformers, industrial motors, air conditioners, lighting, and other products that consume significant amounts of electricity.

Renewable Energy Production Incentive

This program provides financial incentive payments for electricity produced and sold by new qualifying renewable energy generation facilities. Qualifying facilities are eligible for annual incentive payments of 1.7 ¢/kWh for the first ten-year period of their operation. Qualifying facilities must use solar, wind, geothermal, or biomass generation technologies. This program should be extended beyond its current sunset date on December 31, 2001.[154] The uncertainty of its extension has several clean energy projects on hold now.

Wind energy projects have proven to be very successful and energy suppliers are just beginning to understand how to integrate wind power into their energy mix. Several large Washington State wind projects backed by the Bonneville Power Administration and the largest wind energy project to date in Colorado, however, are currently on hold awaiting the decision on the extension of this program. Although wind is currently the least expensive renewable energy source, incentive is needed to pave the way for its widespread utilization.

Interconnection Standards and Net Metering Regulations

Not only can renewable energy sources operate like traditional power plants, dispatching their power through the infrastructure of power lines, but they can also generate electricity onsite. Onsite electricity generation saves energy and money in several ways: 1) it can match the power needs of the onsite home, building, or district accurately, 2) it eliminates the losses of energy that occur in long-distance transmission, and 3) excess power generated at onsite locations can be sent to central power plants for distribution elsewhere, reducing the number of new central power plants needed. However, current interconnection penalties and barriers limit our ability to effectively harness electricity generated from these sources. Setting uniform and consumer-friendly interconnection standards would address the inconsistencies that now exist. Net metering standards, as described in the state policy section above, should be set without caps to encourage onsite clean electricity generation.

Expansion of Federal Energy Efficiency and Renewable Energy Research and Development Funding

Energy efficiency offers the fastest, cleanest, and cheapest solution to the nation’s power needs, and renewable energy technologies are essential for the U.S. to develop and maintain a sustainable energy system. Congress should increase funding for research and development of these technologies.

Carbon Tax

Currently, the costs of environmental and public health damages caused by CO_2 emissions power plant from fossil fuel combustion are not accounted for in the electricity generation industry. A carbon tax would assign responsibility of these costs to the appropriate sources, instead of passing them on to other sectors of society. A carbon tax should be adopted for the electricity industry.

Retirement Plan for Grandfathered Coal Plants

The Clean Air Act of 1970, as amended in 1977 and 1990, exempts coal-burning power plants from new source standards, allowing them to emit four to ten times the amount of pollution that new plants may emit under the Clean Air Act. These grandfathered coal power plants should be required to meet the same air pollution standards as new power plants. Otherwise these plants should be retired and replaced by renewable energy technologies, low-carbon technologies, or energy efficiency.

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