American Energy

The Renewable Path to Energy Security

Worldwatch Institute
Center for American Progress

Worldwatch Institute

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American Energy

The Renewable Path to Energy Security

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September 2006

The American Energy Vision

America is a nation blessed with bountiful natural resources and boundless entrepreneurial spirit. We have always prospered by facing daunting challenges and transforming them into opportunities for innovation, industry, and growth. From the opening of the transcontinental railway to the development of the microchip and the Internet revolution, America has always risen to great challenges to become a stronger and more prosperous nation.

Today, America faces grave challenges in the field of energy—from the gathering storm of global warming to a dangerous addiction to oil that jeopardizes our national and economic security. We must meet these twin threats of climate change and oil dependence head-on, with that same spirit of hope and optimism that has characterized our finest hours.

We, as a nation, have the ingenuity, know-how, and determination necessary to create an energy-secure America. By working together, we can find exciting new ways to build America's use of domestic, non-polluting renewable energy. By capturing the energy of the wind and the light of sun, the power of a mighty river or heat stored in the crust of the Earth, we can find new untapped resources that create jobs, improve our security, and build the health of our people, our planet, and our economy.

American Energy: The Renewable Path to Energy Security shows that an energy future based on abundant and clean renewable resources is not only urgently needed, but achievable. The time is ripe for a strong national commitment to enacting new policies at the federal, state, and local levels that will allow the United States to become a world leader in building a 21st century energy system. Meeting that challenge will require concerted action by governments, businesses, and citizens across our nation.

We are committed to mobilizing our friends, communities, and leaders to share in this vision for a clean, secure, and prosperous future with American Energy.

To sign the American Energy Vision Statement, download the report, and learn more about what you can do to bring about an energy-secure America, visit www.americanenergynow.org.

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21ST CENTURY ENERGY

If there was ever a time when a major shift in the U.S. energy economy was possible, it is now. Three decades of pioneering research and development by both the government and the private sector have yielded a host of promising new technologies that turn abundant domestic energy sources—including solar, wind, geothermal, hydro, biomass, and ocean energy—into transportation fuels, electricity, and heat.

Today, renewable resources provide just over 6 percent of total U.S. energy, but that figure could increase rapidly in the years ahead. Many of the new technologies that harness renewables are, or soon will be, economically competitive with the fossil fuels that meet 85 percent of U.S. energy needs. With oil prices soaring, the security risks of petroleum dependence growing, and the environmental costs of today's fuels becoming more apparent, the country faces compelling reasons to put these technologies to use on a large scale.

NREL

Wind turbines in Minnesota cornfield.

Energy transitions take time, and no single technology will solve our energy problems. But renewable energy technologies, combined with substantial improvements in energy efficiency, have the potential to gradually transform the U.S. energy system in ways that will benefit all Americans. The transition is easier to envision if you look at the way the oil age emerged rapidly and unexpectedly in the first two decades of the 20th century, propelled by technologies such as refineries and internal combustion engines and driven by the efforts of entrepreneurs such as John D. Rockefeller.

Americans today are no less clever or ambitious than their great-grandparents were. A new and better energy future is possible if the country can forge a compelling vision of where it wants to be. Recent developments in the global marketplace show the potential:

- Global wind energy generation has more than tripled since 2000, providing enough electricity to power the homes of about 30 million Americans. The United States led the world in wind energy installations in 2005.
- Production of electricity-generating solar cells is one of the world's fastest growing industries, up 45 percent in 2005 to six times the level in 2000.
- Production of fuel ethanol from crops more than doubled between 2000 and 2005, and biodiesel from vegetable oil and waste expanded nearly four-fold over this period.

Global investment in renewable energy (excluding large hydropower) in 2005 is estimated at $38 billion—equivalent to nearly 20 percent of total annual investment in the electric power sector. Renewable energy investments have nearly doubled over the past three years, and have increased six-fold since 1995. Next to the Internet, new energy technology has become one of the hottest investment fields for venture capitalists.

These dynamic growth rates are driving down costs and spurring rapid advances in technologies. They are also creating new economic opportunities for people around the globe. Today, renewable energy manufacturing, operations, and maintenance provide approximately two million jobs worldwide.

The United States will need a much stronger commitment to renewable energy if it is to take advantage of these opportunities. As President Bush has said, America is "addicted to oil," and dependence on fossil fuels is rising, even in the face of high oil prices and growing concern about global warming. Of particular concern is the well over 100 coal-fired power plants now on the drawing boards of the U.S. electricity industry—most of which lack the latest pollution controls and could still be pumping carbon dioxide into the atmosphere a half-century from now.

In order to break the national addiction to outdated fuels and technologies, America will need a world-class energy policy. The prominent positions that Germany and Spain hold in wind power, for example, and that Japan and Germany enjoy in solar energy, were achieved thanks to strong and enduring policies that their legislatures adopted in the 1990s. These policies created steadily growing markets for renewable energy technologies, fueling the development of robust new manufacturing industries.

By contrast, U.S. renewable energy policies over the past two decades have been an ever-changing patchwork. Abrupt changes in direction at both the state and federal levels have deterred investors and led dozens of companies into bankruptcy. If America is to join the world leaders and achieve the nation's full potential for renewable energy, it will need world-class energy policies based on a sustained and consistent policy framework at the local, state, and national levels.

Across the country, the tide has begun to turn. All but four U.S. states now have incentives in place to promote renewable energy. More than a dozen have enacted new renewable energy laws in the past few years, and four states strengthened their targets in 2005, signaling fresh political momentum. If such policies continue to proliferate, and are joined by federal leadership, rapid progress is possible.

Several states are demonstrating just how quickly renewable energy can take hold with the right policies. California already gets 31 percent of its electricity from renewable resources; 12 percent of this comes from non-hydro sources such as wind and geothermal energy. Texas, whose history is closely identified with the oil industry, now has the country's largest collection of wind generators. And Iowa produces enough ethanol that if this were all consumed in-state, it would meet half the state's gasoline requirements.

A national coalition of more than 200 business and citizens organizations—led by the farm and forestry sectors—has proposed a national commitment to obtaining 25 percent of U.S. energy from renewable resources by 2025. A new economic analysis by the Rand Corporation for the Energy Future Coalition concludes that if the United States were to get 25 percent of its electric power and transportation fuels from renewable energy by 2025, the country's energy costs would be reduced, with large savings occurring by 2015. And national carbon dioxide emissions would fall by one billion tons.

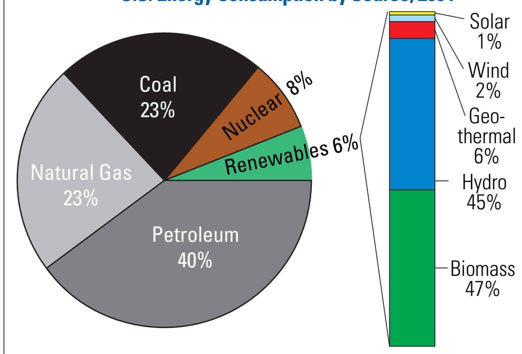
What would a U.S. economy powered by renewable energy look like? Likely changes include:

- The energy economy would become more decentralized and efficient, allowing homes and businesses to meet many of their own energy needs.
- Dependence on Persian Gulf oil would decline, improving U.S. national security.
- Trade deficits would fall as oil imports decline, reducing the roughly $300 billion the United States is expected to spend on imported oil in 2006.
- The air would be cleaner, reducing asthma and other respiratory diseases and saving American lives.
- Emissions of global warming gases would decline, reducing the threat to cities and coastal properties from rising sea level and the threat to agriculture from drought and higher temperatures.
- Hundreds of thousands of new jobs would be created in the agricultural, manufacturing, and service companies that would emerge to meet the demand for renewable energy.
- Rural communities would be revitalized as farmers and ranchers, who own the land where much of the renewable energy can be harnessed, would reap the benefits.

This vision will become reality only if Americans come together to achieve it, mobilized behind the goal of increasing our national self-reliance and leaving a healthy environment for the next generation. The time is now.

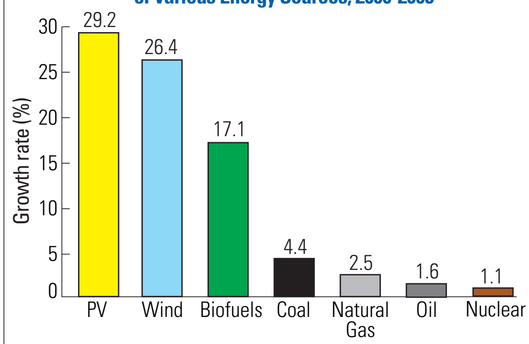
Source: EIA

U.S. Energy Consumption by Source, 2004



Source: BP, Worldwatch

Average Annual Global Growth Rates of Various Energy Sources, 2000-2005



Enhancing Energy Security

America's dependence on imported oil is undermining the country's national security by tying the U.S. economy to unstable and undemocratic nations, thus increasing the risk of military conflict in political hotspots around the globe. Renewable energy can reduce oil dependence and improve the country's security in several key ways.

The United States currently imports some 13 million barrels of oil each day—over 60 percent of its total daily consumption—at an annual cost of $300 billion. If current trends continue, America will depend on imports for 70 percent of its oil by 2025. As President Bush said in his 2006 State of the Union address, America is "addicted to oil." This addiction requires billions of dollars in military expenditures to secure the country's energy supply lines.

AP Images

Oil pipeline damaged by Iraqi insurgents, 2005.

The United States was once the world's largest oil exporter, but domestic production peaked in 1970. More recently, oil production has peaked in countries such as Indonesia, Norway, and the United Kingdom. As accessible reserves in the world's stable regions have been depleted, oil extraction has gradually shifted to more dangerous corners of the globe. Today, the world's oil frontier includes a list of countries that mirrors a catalog of global trouble spots, including Angola, Azerbaijan, Chad, Nigeria, Sudan, and Venezuela.

Most of these countries rank disturbingly low in many measures of political liberty, human rights, and corruption. Furthermore, an estimated 85 percent of the world's oil reserves are now either owned or controlled by national petroleum companies, which greatly limits private investment in exploration and infrastructure development.

The Middle East contains a remarkable 60 percent of the world's remaining proven oil reserves, and each day, nearly half the world's oil exports travel through the Straits of Hormuz at the mouth of the Persian Gulf. Because of their geographical proximity, Europe and Asia import a larger share of their oil from the Middle East than the United States does. But this does not lessen the U.S. exposure to imported oil. For three decades, the Middle East has been the world's marginal oil supplier, and disruptions in the flow of oil are reflected in the world price of energy and the balance of global economic power.

In recent years, however, even the large oil reserves in the Persian Gulf have been insufficient to keep up with rising global demand, most of it coming from the United States, the Middle East, China, and other Asian countries. If supply fails to keep up with rising demand, oil prices could rise far above their recent record highs. Every oil price spike over the past 30 years has led to an economic recession in the United States; such price spikes will become more frequent as global competition for remaining oil supplies intensifies.

Full U.S. energy independence will take decades to achieve; until then, national security could be greatly improved if America moved from its current path of rising oil imports to reducing national reliance on oil. That is an eminently achievable goal—through both transportation efficiency improvements and increased reliance on biofuels and other renewable resources.

Improving efficiency and diversifying fuel choices will take the pressure off energy prices, while enabling the country to make diplomatic and security decisions based on American interests and values rather than the relentless need to protect access to oil. In many areas of the world, the U.S. diplomatic hand would be greatly strengthened if energy imports were going down rather than up.

America's current energy system undermines national security in other ways as well. The centralized and geographically concentrated nature of the country's power plants, refineries, pipelines, and other infrastructure leaves it vulnerable to everything from natural disasters to terrorist attacks. One year after Hurricane Katrina crippled approximately 10 percent of the nation's oil refining capacity, oil and gas production and transportation in the Gulf of Mexico still had not been fully restored.

Security experts believe that a well-orchestrated physical or electronic attack on the U.S. electricity grid could cripple the economy for an extended period. It is estimated that the 2003 Northeast blackout cost between $4 billion and $10 billion over the course of just a few days.

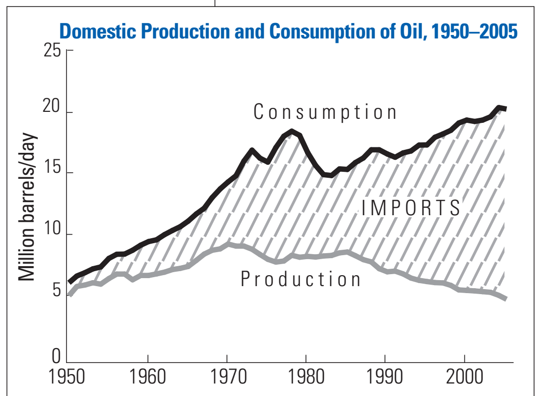
The country's 104 nuclear power plants and their associated pools of high-level radioactive waste present another U.S. security threat. If one of the planes that struck the World Trade Center on September 11, 2001, had instead hit the Indian Point nuclear plant just north of New York City, the human and economic toll of that fateful day could have been vastly greater.

The distributed nature of many renewable energy technologies helps reduce the risk of accidental or premeditated grid failures cascading out of control. An analysis of the 2003 Northeast blackout suggests that solar power generation representing just a small percentage of peak load and located at key spots in the region would have significantly reduced the extent of the power outages.

A 2005 study by the U.S. Department of Defense found that renewable energy can enhance the military's mission, providing flexible, reliable, and secure electricity supplies for many installations and generating power for perimeter security devices at remote installations. Renewable energy provided more than 8 percent of all electricity for U.S. military installations by the end of 2005. Both the military and the Central Intelligence Agency are turning to new lightweight solar technologies to replace heavy batteries in the field and for use in intelligence applications.

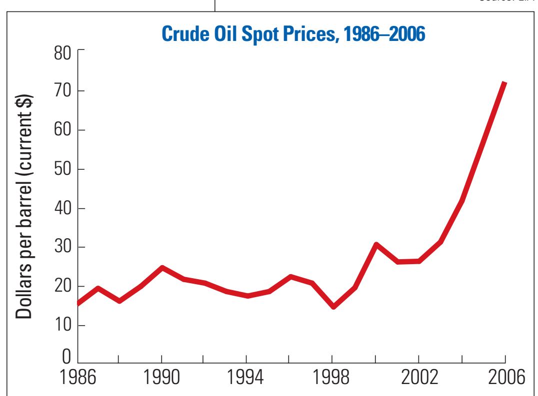
Renewable energy can play an important role in providing power to critical infrastructure in the aftermath of catastrophes as well. For example, the Louisiana State Police used solar-powered lighting in critical areas around New Orleans following Hurricane Katrina; elsewhere in Louisiana, the lack of power slowed the work of emergency and recovery workers. Officials at New Jersey's Atlantic County Utilities Authority plan to install solar and wind power at a waste-water facility to keep the plant operating during blackouts.

Source: EIA



Renewable technologies can be coupled with traditional backup diesel generators to extend the fuel supply and increase the total power available. Renewable power can also come back on line much more quickly than coal or nuclear power plants can, helping to reduce economic losses associated with power failures and minimize the time that critical facilities such as hospitals and emergency communication centers must go without power, thus saving lives. Some states already view solar power, wind power, and other distributed technologies such as fuel cells as essential for public safety and emergency preparedness.

Source: EIA



As with oil dependence, the broader energy security threats cannot be eliminated overnight. But immediate steps to invest in a diverse, decentralized energy system that relies more heavily on domestic renewable resources will allow the United States to steadily enhance its security in the years ahead.

Creating Jobs

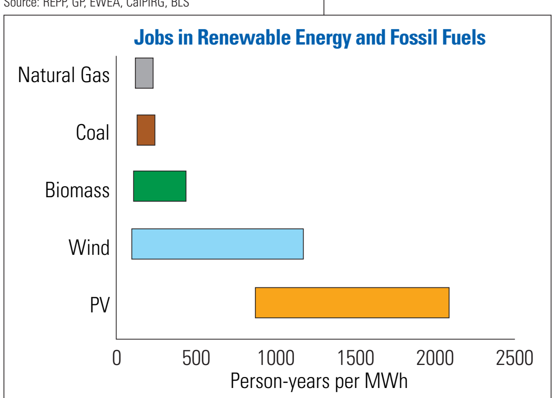
Expanding the use of renewable energy will have a positive impact on employment, according to more than a dozen independent studies analyzing the impact of clean energy on the economy. Renewable energy creates more jobs per unit of energy produced and per dollar spent than fossil fuel technologies do. Several studies have shown that greater reliance on renewable energy would have large, positive impacts on the U.S. economy, creating significant numbers of new jobs, driving major capital investment, stabilizing energy prices, and reducing consumer costs.

PowerLight Corporation

Installing PV system.

A transition away from fossil fuels and toward renewable energy would create both winners and losers, but most studies show that many more jobs would be created than lost. A 2004 analysis by the Union of Concerned Scientists found that increasing the share of renewable energy in the U.S. electricity system to 20 percent—adding more than 160,000 megawatts (MW) of new renewable energy facilities by 2020—would create more than 355,000 new U.S. jobs.

Source: REPP, GP, EWEA, CalPIRG, BLS



If the increased use of renewable energy led to significant reductions in fossil fuel prices, consumer savings on electricity and natural gas bills would ripple through the U.S. economy, spawning even more jobs. It would also provide a tremendous economic boost to rural communities. Most of the jobs created in renewable energy would be high-paying positions for skilled workers, in fields such as manufacturing, sales, construction, installation, and maintenance.

A 2004 Renewable Energy Policy Project study determined that increasing U.S. wind capacity to 50,000 MW—about five times today's level—would create 150,000 manufacturing jobs, while pumping $20 billion in investment into the national economy. Renewable heating and biofuels also offer significant employment opportunities. The U.S. ethanol industry created nearly 154,000 jobs throughout the nation's economy in 2005 alone, boosting household income by $5.7 billion.

Booming markets for renewables around the world may provide additional opportunities for U.S. companies and workers. A 2003 study by the Environment California Research and Policy Center determined that California's Renewable Portfolio Standard—which required that 20 percent of electricity come from renewable sources by 2017 (a target date since pushed to 2010)—would create a total of some 200,000 person-years of employment over the lifetimes of plants built through that period, at an average annual salary of $40,000. An estimated 78,000 of these jobs would serve overseas export markets.

By contrast, employment in the fossil fuel industries has been in steady decline for decades, in large measure due to growing automation of coal mining and other processes. Between 1980 and 1999, while U.S. coal production increased 32 percent, related employment declined 66 percent, from 242,000 to 83,000 workers. The coal industry is expected to lose an additional 30,000-some jobs by 2020, even if coal demand continues to rise. Further, high prices for fossil fuels have a negative impact on the economy, even leading to the transfer of manufacturing jobs overseas. Expanding the use of renewable energy can help minimize these losses and provide new opportunities for displaced workers.

The Global Marketplace

Renewable energy is rapidly becoming big business around the world. Between the mid-1990s and 2005, annual global investments in "new" renewable energy technologies (excluding large hydropower and traditional biomass) rose from $6.4 billion to $38 billion. It is estimated that investment in renewable energy technology could approach $70 billion by 2010.

Wind and solar power are the world's fastest growing energy sources today, with capacity expanding at double-digit rates every year over the past decade. Other sources are growing rapidly as well, at rates far outpacing those for traditional energy sources. The global power industry is now adding more wind energy generating capacity to the world's grids each year than it is nuclear capacity. Solar thermal capacity for domestic hot water and space heating increased 16 percent in 2005, while global production of ethanol and biodiesel grew by nearly 20 percent and 60 percent respectively that year.

The effects of such rapid growth include impressive technology advances, dramatic cost reductions, and an increase in political support for renewable energy around the world. Not surprisingly, these industries are attracting some of the largest players in the world energy market, including BP, Royal Dutch/Shell, and General Electric (which has moved into both the wind and solar cell markets in recent years). They are even drawing other major companies—including Dupont and Honda—into the energy arena for the first time.

Most of the investment to date has occurred in a relatively small number of countries, driven by consistent, forward-looking policies that aim to create markets for renewable energy. Germany and Spain, for example, have forged a dominant position in wind energy over the past decade, and are now turning to other renewables as well. Japan and Germany lead in solar electricity, with Japan responsible for nearly half of global solar cell production and Germany dominating the marketplace. Brazil has moved to the forefront of biofuel production with its successful alcohol fuels program. And China is the world leader in small hydropower and solar water heating, with well over half the global market in each.

Despite strong public support and rapidly rising interest in renewable energy, the United States has not kept up with the strong growth in renewables over the past decade; as a result, its market share has fallen steadily. For example, while U.S. solar cell manufacturing has risen year by year, the nation's share of global production has declined from 44 percent in 1996 to below 9 percent in 2005.

Time is growing short for the United States to get back in the game and compete for what could be some of the largest new markets of the next few decades. A strong partnership between government and the private sector is essential if that kind of leadership is to be achieved.

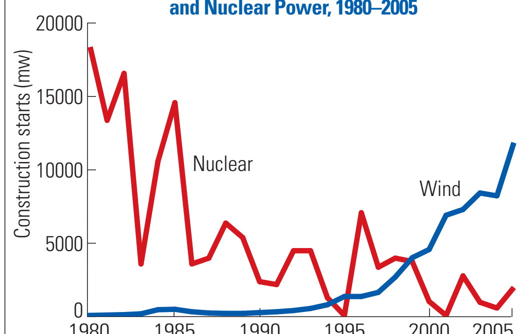
New York Stock Exchange.

Green Power Markets

Voluntary purchases have played a major role in driving the U.S. renewable energy market. By the end of 2004, "green power" demand had topped 2,200 MW of renewable capacity, up from 167 MW in 2000. The U.S. Air Force is the nation's leader in green power purchasing, followed by Whole Foods Market and a growing list of corporate and government offices. The Statue of Liberty now gets 100 percent of her power from renewable energy. In most cases, green power subscribers pay a premium price for electricity, but some customers in Colorado and Texas are now paying less than non-subscribers due to rising natural gas prices.

Source: Worldwatch, BTM Consult, AWEA, EWEA

Global Construction Starts for Wind and Nuclear Power, 1980–2005



Investment Opportunities

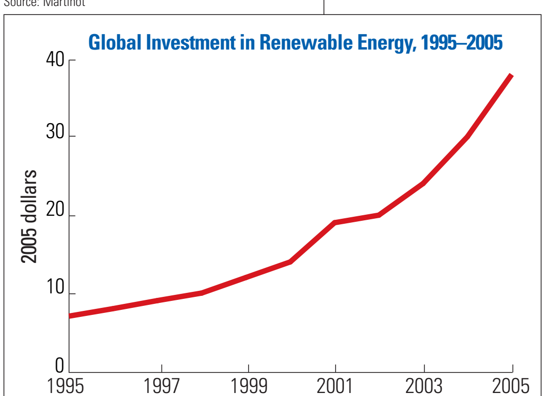
Annual global investment in "new" renewable energy has risen almost six-fold since 1995, with cumulative investment over this period of nearly $180 billion. The $38 billion invested in renewables in 2005 compares to the roughly $150 billion invested worldwide in the conventional power sector in 2004. Market growth has been driven by technology improvements, rising fossil fuel prices, government policies, and the growing familiarity of investors and lenders with the opportunities and risks posed by the wide range of renewable technologies and projects.

ACORE/Euromoney Energy Events

Poster for Renewable Energy Finance Forum, Wall Street, 2006.

Renewable energy technologies tend to be more capital intensive than traditional fossil fuel technologies, with higher upfront costs. At the same time, they do not expose owners to the risks of fuel price increases or the cost of future retrofits or penalties associated with climate change and other environmental and health problems. As a result, renewable and fossil fuel projects have very different financial profiles.

Source: Martinot



In light of the long-term risks of investing in conventional energy systems, institutional investors, such as the California Public Employees Retirement System (CalPERS), have begun directing large blocks of funds to the environmental sector, including to renewable energy, much of it under the rubric of sustainable or socially responsible investing.

But investing in renewables is no longer just about doing the right thing; it's also about making money. Renewable energy is increasingly viewed as an attractive investment by private and public equity investors alike.

In November 2005, Goldman Sachs committed to investing more than $1 billion in renewable energy projects, including biofuels, solar power, and wind energy. The Nasdaq stock market launched its "Clean Edge U.S. Index" in May 2006 to track the performance of clean energy companies, including several in the renewable energy and efficiency industries. In the world of venture capital, clean energy is the hottest new investment arena, having just passed semiconductors in annual deal flow, according to the Cleantech Venture Network. Kleiner Perkins general partner John Doerr, one of the first investors in Google, believes that green technologies "could be the largest economic opportunity of the 21st century."

Project lenders, principally banks, are providing loans to ethanol plants, wind farms, and other large-scale renewable power projects, and direct lending by U.S. banks and institutional investors is on the upswing. Still, U.S. banks lag behind those in Europe. One reason is that the financing of renewable energy projects in the United States is dominated by equity investments by the unregulated subsidiaries of electric utility companies, which benefit from the Production Tax Credit (PTC). The PTC has been available for wind power and certain waste projects, and was expanded in late 2004 to include solar, biomass, and geothermal power plants.

The scores of ethanol plants now under construction are being financed by a wide array of agricultural coops, corporations such as Archer Daniels Midland, and equity investors ranging from large institutions to Microsoft Chairman Bill Gates.

Public sector financing of renewable energy projects has been evolving for several years and is likely to increase substantially in the near term. By mid-2005, 17 Clean Energy Funds worth nearly $3.5 billion had been established in 13 states to support renewable energy development through grants, subsidies, loans, and investments that often leverage private sector financing. Cities are getting involved as well, using bond financing for renewable energy and energy efficiency projects.

Building for the Future

Commercial and residential buildings consume about one-third of all U.S. energy and two-thirds of U.S. electricity. In addition, they account for more carbon emissions than any other sector. But buildings' demand for energy can be dramatically reduced, and renewable energy can meet a significant share of the remaining needs.

The burgeoning "green building" movement seeks to tap consumer demand for environmentally friendly, healthy, and affordable homes and offices. Designers of green buildings aim to minimize energy consumption with more-efficient materials and appliances and integrated renewable energy systems; to reduce demand for water and open space; to use sustainably produced products (including recycled materials); and to provide convenient access to public transportation.

The movement officially began with the founding of the U.S. Green Building Council, which in 2000 published LEED (Leadership in Energy and Environmental Design) standards to guide developers' decisions on site design, water use, indoor air quality, and energy generation and use. Today, nearly 6,000 member organizations and companies plan to construct new buildings or renovate old ones according to LEED standards, and a growing number of state and local governments—including in Atlanta, Boston, and San Francisco—have incorporated them into laws and regulations for new public buildings. By mid-2006, nearly 500 U.S. buildings were LEED certified.

Solar energy is playing a role in many of these buildings. The pharmacy chain Walgreens plans to install solar photovoltaics (PVs) on 112 of its stores, enabling the facilities to meet 20–50 percent of their power needs on site. In Battery Park in New York City, developers built the world's first green high-rise. The "Solaire" apartments use 35 percent less energy and 65 percent less electricity than an average building, with solar cells meeting at least 5 percent of demand. By 2009, all developments covering Battery Park City's 92 acres will be LEED certified and will have solar panels.

The Chicago Center for Green Technology uses geothermal energy for heating and cooling, and the Dallas/Fort Worth Airport relies on solar energy for air conditioning, reducing cooling costs by 91 percent at times of peak demand. And major housing developers such as Centex and Premier Homes are now incorporating solar into new homes in California.

There are good economic reasons for constructing green buildings, which generally have healthier employees, higher worker productivity, lower turnover, and significant energy and water savings. A study by the California Sustainable Building Task Force found that an upfront investment of 2 percent (the average cost premium) in green-building design results in average savings of at least 10 times the initial investment over a 20-year period. And costs are falling as those who design, construct, and maintain green buildings gain experience. Further, green buildings tend to have higher occupancy rates and rents, and therefore better returns on investment, than conventional buildings. And generating power and heat on-site with renewable energy can reduce the chances of a power outage, while hedging against an increase in electricity prices.

Brad Keinknopf

David L. Lawrence Convention Center, Pittsburgh, Pennsylvania.

More Examples of Green Buildings in the United States

Ford Motor Company installed a "green roof" on the 10.4-acre rooftop of its Rouge River Plant in Michigan in 2004. Replacing dark, heat-absorbing roof surfaces with plants keeps buildings cooler in summer and warmer in winter, reducing energy use for heating and cooling by 10–50 percent; it also filters the air and rainwater.

A new building at the Natural Energy Laboratory of Hawaii is "net zero energy," using no electricity from the grid. Seawater is piped in for space cooling, and condensation from the pipes is used for irrigation.

The office tower 4 Times Square, headquarters of Condé Nast, is powered by fuel cells and has a PV façade; recycled materials make up 20 percent of the building.

Pittsburgh's David L. Lawrence Convention Center includes numerous features that reduce the energy bill by at least one-third, or enough to meet the needs of 1,900 households. Its curved roof allows hot air to escape through vents and cool breezes to flow in from the river. Construction costs were comparable to or lower than other (non-green) centers built in recent years.

Genzyme's headquarters in Cambridge, Massachusetts, was the first large U.S. office building to achieve "platinum" LEED standards, the highest level of certification. The building includes a green roof, uses natural light and ventilation, is sited on a reclaimed brownfield and close to a subway station, and provides indoor bike storage, showers, and lockers for employees.

Meeting the Transportation Challenge

Transportation accounts for two-thirds of U.S. oil consumption and is the predominant source of domestic urban air pollution. Recent gasoline price increases have combined with growing environmental concerns to spur interest in new fuels to run the nation's transportation fleet, which relies on oil for more than 95 percent of its energy. Renewable fuels currently represent only around 2 percent of the total.

NREL

Bus fueled by soy biodiesel.

The immediate options for running the U.S. transportation system on renewable energy are more limited than those for other sectors of the economy, such as buildings and industry. In the short term, the main potential is in the use of biofuels derived from crops and wastes. In the long term, electricity and hydrogen derived from sources like wind and solar energy are likely to become viable alternatives.

Source: EIA

Estimated Number of Alternative-Fueled Vehicles in Use in the United States, by Fuel, 2000 and 2004

Fuel	2000	2004
Liquefied Petroleum Gases (LPG)	4,435	9,036
Natural Gas	9,912	4,292
Hydrogen	0	77
Ethanol	600,832	652,779
Electricity	18,172	2,633
Total	633,351	668,817

Most cars and SUVs on the road today can run on blends of up to 10 percent ethanol, and motor vehicle manufacturers already produce vehicles designed to run on much higher ethanol blends. Ford, DaimlerChrysler, and GM are among the automobile companies that sell "flexible-fuel" cars, trucks, and minivans that can use gasoline and ethanol blends ranging from pure gasoline up to 85 percent ethanol (E85). By mid-2006, there were approximately six million E85-compatible vehicles on U.S. roads.

The goal now is to expand the market for biofuels beyond the farm states where they have been most popular to date. Flex-fuel vehicles are assisting in this transition because they allow drivers to choose different fuels based on price and availability. The Energy Policy Act of 2005, which calls for 7.5 billion gallons of biofuels to be used annually by 2012, will also help to expand the market.

The impact of bio-fueled cars can be maximized by making them as efficient as possible. A new generation of highly efficient and clean-burning diesel engines is one option. Another is hybrid gas-electric technology that is up to 30 percent more fuel efficient than conventional vehicle technology.

A federal law provides tax credits for purchasers of hybrid and alternative fuel vehicles. Many states also offer incentives for buying these vehicles. The same "green" consumers who have made hybrid gas-electric vehicles hot items in auto showrooms in recent years are now showing strong interest in biodiesel and other renewable fuels.

Running motor vehicles on solar energy and wind power is more challenging, though not a pipe dream. Electric cars on the market today can be plugged into an outlet and recharged at home. Homeowners with rooftop solar systems—or in regions rich in hydro or wind power—can already fuel their vehicles with renewably generated electricity. And a new generation of plug-in hybrids will soon provide a similar opportunity, while giving drivers the option of extending the typical 100-mile range of an electric vehicle by using gasoline or biofuel in the tank.

In the more distant future, hydrogen offers a means of storing energy sources such as solar and wind power. Hydrogen can be produced from water using any energy source that generates electricity. Because it can be readily stored in tanks and transported in pipelines, hydrogen is a logical long-term replacement for oil and natural gas. A new generation of experimental fuel-cell vehicles is being developed that efficiently uses hydrogen to turn the wheels, with water vapor the only tailpipe emission.

As renewable energy becomes a larger part of the electricity system and as costs decline, renewably generated hydrogen is likely to become a growing part of the transportation fuel mix.

A New Future for Agriculture

Renewable energy—particularly biofuels and wind power—could provide a new source of revenue for thousands of farmers and agricultural processors, creating economic opportunities in rural areas that have suffered from decades of falling crop prices. Already, the growing ethanol and biodiesel industries are providing jobs in plant construction, operations, and maintenance, mostly in rural communities. According to the Renewable Fuels Association, the ethanol industry created almost 154,000 U.S. jobs in 2005 alone, boosting household income by $5.7 billion. It also contributed about $3.5 billion in tax revenues at the local, state, and federal levels.

The emerging industry of cellulosic ethanol, with its low-cost feedstock and new conversion techniques, is poised to offer even greater economic and environmental benefits. Farmers can reduce disposal costs and gain a secondary source of income by converting high-cellulose crop residues into fuel. Marginal land that is unsuitable for most cultivation can be planted with a variety of fast-growing energy crops that are less resource-intensive than annual crops, require less maintenance, and can improve degraded soils while providing wildlife habitat.

People in rural areas can benefit from biofuels in three ways: wealth remains in the local community, farmers are paid for producing feedstock, and biofuels provide them with cleaner energy at lower cost (nearly half of U.S. soybean farmers now use biodiesel, for example). Some proponents foresee a future in which local "bio-refineries" churn out a combination of fuels, chemicals, pharmaceuticals, and plastics—creating local jobs and tax revenues while gradually replacing the oil refineries that are central to today's oil-based economy.

Farmers and rural communities can also increase their revenue by tapping local wind resources to generate electricity. Some of the country's most valuable winds sweep across some of its poorest farmlands. Here, farmers and ranchers can generate income even when cropland is parched from drought. They can become wind developers themselves, or opt to have others install turbines on their land and, in turn, receive annual lease payments or share the revenues from a wind project.

Horizon Wind Energy

Cows grazing beneath turbines, Blue Canyon Wind Project, Oklahoma.

Payments range from $1,000 to $4,000 a year for each wind turbine installed, as much as doubling the economic yield from the land. While turbines harness the wind, farmers and ranchers can continue to raise crops and livestock beneath them.

Solar energy benefits farmers as well, by lighting and heating buildings and greenhouses, drying crops, and powering water pumps and irrigation systems. One of California's largest vegetable growers now irrigates 600 acres of farmland with solar power, helping to ease pressure on the California electricity grid during peak demand periods.

In early 2006, rising awareness of the myriad benefits of renewable energy led a cross-section of agriculture and forestry groups to launch "25 x '25," a call to meet 25 percent of total U.S. energy demand by the year 2025 with clean, secure, and renewable energy from America's farms, ranches, and forests. The movement is quickly gathering steam, with support from a broad coalition of forces, including the agriculture and forestry communities, organized labor, businesses, security hawks, and religious and environmental groups. By mid-2006, 25 x '25 had been endorsed by 13 governors and 4 state legislatures, 32 U.S. Congressmen, and a bipartisan group of 19 influential U.S. Senators.

Powering the Electricity Grid

Paul Langrock/Zenit/Greenpeace

Wind farm with transmission tower.

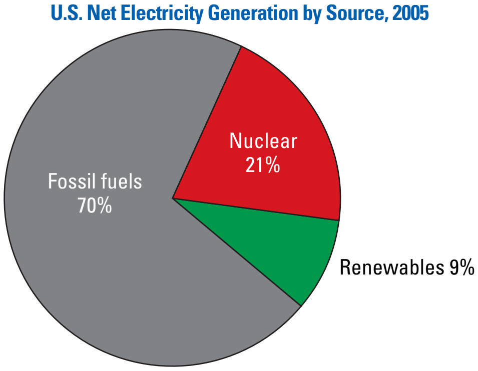
The U.S. economy, as well as public health and safety, depends on a reliable power system that provides electricity 24 hours a day, 365 days a year. The costly disruptions resulting from the Northeast blackout of August 2003 were a powerful reminder of how dependent the country is on the reliability of large power plants and the transmission networks that connect them.

The U.S. electric power industry now relies on large, central power stations, including coal, natural gas, nuclear, and hydropower plants that together generate more than 95 percent of the nation's electricity. Over the next few decades, renewable energy could help to diversify the nation's bulk power supply. Already, renewable resources (excluding large hydropower) produce 12 percent of northern California's electricity.

Most electric utilities operate a combination of baseload plants (often coal and nuclear) that operate most of the time and others (often natural gas) that are utilized only when demand is high. Some renewable power plants can provide steady power whenever it's needed—using geothermal, concentrating solar (with storage), and bioenergy, for example. Other power sources are intermittent, meaning they are available only when the sun is shining or the wind is blowing. Yet even intermittent sources can add significant value to the system by providing electricity when it is most needed and most costly to produce with conventional sources. In many parts of the country, for example, periods of peak sunlight coincide with peak power demand for air conditioning.

Source: EIA

U.S. Net Electricity Generation by Source, 2005



All power systems rely on backup generators, since even baseload plants must close occasionally due to technical problems. In the case of intermittent renewables, wind resources can already be forecast at least two days in advance, and fluctuations in power output can be reduced if not eliminated by spreading solar or wind generators across a sufficiently wide region. Studies show that even when wind power alone provides 20 percent of the total electricity on a regional grid—as it does in Denmark and large parts of Germany—backup capacity is rarely needed. Above that level, some backup capacity may be required, but at much less than a 1:1 ratio. In the future, new technologies like advanced gas turbines and fuel cells, as well as new storage devices, will likely reduce the cost of providing backup capacity, allowing much higher levels of dependence on intermittent generators.

Renewable energy sources also provide grid operators with real economic benefits (in addition to their peaking value) that are just beginning to be recognized. Conventional power plants based on coal and nuclear power can take 5–15 years to plan and construct, a serious disadvantage given the uncertainties of future power demand and the risks of borrowing hundreds of millions of dollars while the plants are built. Construction lead times for large renewable projects are often in the range of 2–5 years, reducing the risk to utilities and allowing capacity to be added incrementally to match load growth. According to FPL Energy, it can take as little as 3–6 months from ground breaking to commercial operation with new wind farms. Once on line, renewable facilities can begin operation more rapidly than conventional power plants after blackouts, reducing associated economic and security costs.

At a time when the price of natural gas, the most popular fuel for recently constructed power plants, has increased significantly, renewable power has become a valuable component of a utility power portfolio and a hedge against future fuel-price increases. Wind farms are already competitive with gas and coal, and GE Wind has predicted that wind turbine sales could surpass gas turbine sales within the next few years. Since renewable power plants are emissions free, or close to it, they also represent a hedge against future environmental regulations, including possible caps on mercury and carbon-dioxide emissions.

Micro Power

Although most of today's electricity comes from large, central-station power plants, new technologies offer a range of options for generating electricity where it is needed, saving on the cost of transmitting and distributing power and improving the overall efficiency and reliability of the system. These new options include renewable energy technologies such as rooftop solar cells and bio-fueled generators, as well as devices such as gas turbines and fuel cells that may run on energy sources derived from fossil fuels.

Micro (or distributed) power is in effect a return to the vision of Thomas Edison, who designed small, city-based power plants, the first of which was built near Wall Street in 1882. Economies of scale quickly rendered this approach obsolete, but new technologies that can be mass-produced at low cost are bringing us back to the future.

Locally based generators that connect to local distribution lines generally have generating capacities of 5 MW or less, and are sited in or adjacent to residential, commercial, or public buildings. These micro power plants provide additional value to the electricity system because they do not require extra investment in transmission or distribution, and they reduce or eliminate line loss. Their popularity is also fueled by the need for reliable power supplies for the electronic equipment that is so central to today's economy. Since most power outages are caused by weather-related damage to power lines, locally based generators can dramatically improve reliability.

Japanese companies have demonstrated that the development of simple, integrated technology packages can quickly and significantly reduce the cost of home-sized solar generators. Recently, U.S. companies have introduced so-called "plug-and-play" solar systems that are modular and elegant—easily integrated into a new or existing building without the need for custom design work. Solar experts believe that as these systems become more standardized, commercial and residential consumers will see the units proliferating in their neighborhoods over the next few years.

One business that has taken advantage of small-scale solar power is the FedEx Corporation. In 2005, FedEx completed a solar electric system atop its hub at Oakland International Airport. The 81,000-square-foot system generates enough electricity to power 900 homes, and provides 80 percent of the facility's peak load while protecting the roof from UV rays and reducing heating and cooling needs.

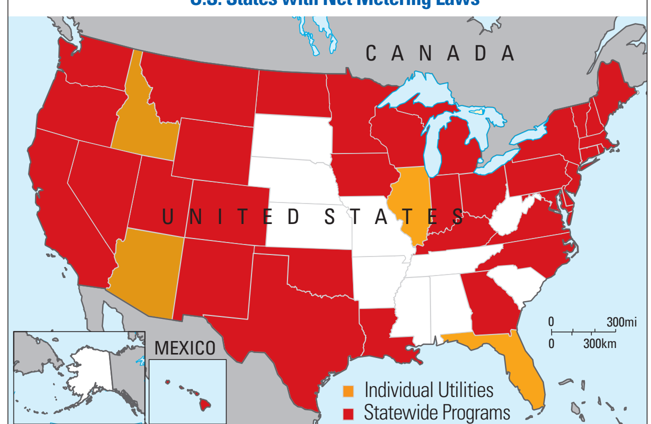
That micro generators are not widely used today reflects in part the fact that everything from electricity laws to environmental and tax regulations are often structured in ways that disadvantage these technologies. Despite such impediments, businesses and consumers increasingly demand the ability to generate their own power and to sell electricity to other consumers at a fair price. Under "net-metering" laws that have been enacted in several states, it is now possible for consumers to sell some of their extra power back to the grid at the same price the consumer pays for it. These laws have helped spur the growing popularity of rooftop solar power systems, particularly in California.

PowerLight Corporation

120 kW solar electric array powering Domaine Carneros' Winery, Napa, California.

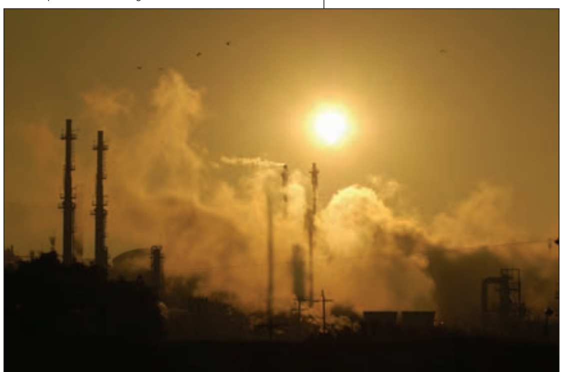
Source: DSIRE

U.S. States with Net Metering Laws



Cleaner Air and Water

Sean Carpenter, Stock.xchng



Emissions from an oil refinery in San Pedro, California.

The emissions-free nature of most renewable energy technologies is one of their principle advantages compared to fossil fuels. Power plants, motor vehicles, and industries that burn fossil fuels emit a host of pollutants that imperil human health, impose heavy economic costs, and degrade the natural environment.

A 2002 study published in the *Journal of the American Medical Association* determined that exposure to air pollution poses the same risks of dying from lung cancer and heart disease as does living with a smoker. A 2004 study by Abt Associates estimated that fine particulate pollution from power plants causes nearly 24,000 premature deaths annually in the United States. Thousands more Americans experience asthma attacks, and millions of workdays are lost annually due to pollution-induced illnesses. The result is more than $160 billion per year in medical expenses due to air pollution from power plants alone.

Sulfur emissions, resulting primarily from the burning of coal in conventional power plants to produce electricity, are the main source of acid rain, which damages crops, forests, and buildings and can make lakes and rivers too acidic to support life. Nitrogen oxides (NOx) combine with other chemicals to form ground-level ozone, or smog. The burning of fossil fuels also releases volatile organic compounds. Some combine with NOx to create smog; others are directly toxic and are associated with cancer, developmental disorders, and adverse neurological and reproductive impacts.

Coal and oil contain toxic metals such as mercury, arsenic, and lead that are released into the air when these fuels are burned and find their way into drinking-water supplies. Coal-fired power plants are the nation's largest human-caused point source of mercury pollution, emitting about 48 tons into the air each year. They alone are responsible for 42 percent of the nation's mercury emissions.

Once in the environment, toxic metals accumulate in fatty tissue of humans and animals. In August 2004, the head of the EPA warned that fish in nearly all of the nation's lakes and streams are contaminated with mercury. Studies show that one in six American women of childbearing age may have blood mercury concentrations high enough to cause damage to a developing fetus. Mercury damage can affect the central nervous system and may damage reproductive, immune, and cardiovascular systems.

Conventional power plants require significant amounts of water for ongoing maintenance and cooling. Withdrawal of surface water can kill fish, larvae, and other organisms trapped against intake structures, while wastewater discharge releases chemicals and heat into surrounding ecosystems, affecting plants, fish, and animals.

Fuel extraction and transport pose severe health and environmental threats as well. Black-lung disease kills an estimated 1,500 former coal miners annually. In the Appalachian states of West Virginia, Kentucky, and Tennessee, mountaintop coal mining (which involves blasting away mountain tops to expose coal seams within) has buried or polluted more than 1,200 miles of streams, destroyed more than 7 percent of Appalachia's forests, and eliminated entire communities. If current trends continue over the next decade, affected land will cover 2,200 square miles, an area larger than the state of Rhode Island.

The European Union has found that environmental and health costs associated with conventional energy and not incorporated into energy prices equal an estimated 1–2 percent of EU gross domestic product, excluding costs associated with climate change. A dramatic increase in our use of renewable energy could significantly reduce these burdens.

Costs of Air Pollution

More than 150 million Americans—more than half the nation's people—live in areas where air quality threatens their health.

A 2005 study by the Mount Sinai School of Medicine's Center for Children's Health and the Environment estimated that the cost in lost productivity to the U.S. economy due to mercury's impact on children's brain development totaled $8.7 billion per year.

Researchers at the Harvard University School of Public Health and Brigham and Women's Hospital in Boston found that each 1 microgram decrease in soot per cubic meter of air reduces by 3 percent the U.S. death rates from cardiovascular disease, respiratory illness, and lung cancer—thereby extending the lives of 75,000 people annually.

The city of Atlanta improved public transit and limited downtown vehicle use for the 1996 Olympic Games, cutting peak ozone concentrations by more than 25 percent and reducing by 42 percent the number of asthma acute care events in the Georgia Medicaid claims files.

Climate Change and Energy

Most renewable energy sources add little or no carbon dioxide (CO_2) to the atmosphere. They are therefore one of the key elements of a global strategy to reduce the threat of climate change.

Atmospheric CO_2 concentrations have climbed 20 percent since measurements began in 1959 and nearly 36 percent since the dawn of the Industrial Revolution. Over the past century, the average global temperature has risen by 1.8 degrees Fahrenheit; more than half of this warming has taken place in the past 30 years. The burning of fossil fuels for energy production and use is responsible for an estimated 70 percent of the global warming problem, and the United States accounts for about one-quarter of total global emissions.

In its 2001 report, the Intergovernmental Panel on Climate Change, the most authoritative scientific body synthesizing the vast research on climate change, concluded that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." Expected impacts of global warming include sea-level rise; flooding of coastal areas; increased frequency and severity of floods, droughts, storms, and heat waves; reduced agricultural production; massive species extinction; and the spread of vector-borne diseases such as malaria and dengue fever.

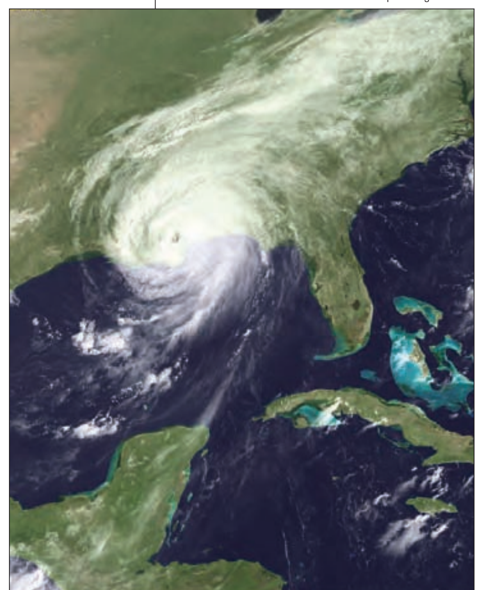
There is growing concern that societies and ecosystems will not have time to adapt to these changing conditions. Rising economic losses due to weather-related disasters are part of a trend being linked to climate change. The World Health Organization estimates that climate change is already responsible for 150,000 deaths annually. While developing countries will likely see the highest toll, impacts will be significant in industrial nations as well, including the United States.

The concentration of CO_2 in Earth's atmosphere is now higher than at any time in the past 650,000 years, and the rate of increase is accelerating. In June 2004, a new, more-accurate atmospheric model revealed that global temperatures could rise more rapidly than previously projected. The extent of warming by the end of this century will be determined by the amount of fossil fuels we continue to burn and the sensitivity of the climate system.

The steady rise of atmospheric CO_2 levels—and the consequent risk of climate change, whether gradual or abrupt—is receiving the attention of everyone from urban planners to Pentagon strategists. U.K. Chief Scientific Advisor David King has said that climate change is "the most severe problem that we are facing today—more serious even than the threat of terrorism." At their July 2005 meeting in Gleneagles, Scotland, G-8 leaders issued a statement acknowledging that "climate change is a serious and long-term challenge that has the potential to affect every part of the globe." And former U.S. president Bill Clinton has warned that climate change is the only problem "that has the power to end the march of civilization as we know it," adding that a "serious global effort" to promote clean energy is required.

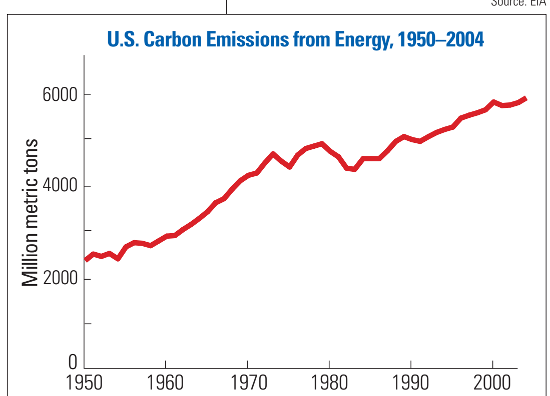
Global emissions must be reduced dramatically over this century to avoid catastrophic climate changes. The sooner societies begin to reduce their emissions, the lower will be the impacts and associated costs of both climate change and emissions reductions. The Kyoto Protocol, which entered into force in early 2005, requires 39 industrial nations to reduce their emissions. Although the United States is not party to the treaty, U.S. companies that operate within signatory countries face pressure to reduce their emissions as well. Dramatically increasing the use of renewable energy, alongside significant improvements in energy efficiency, will provide an important means of doing so.

NASA-Goddard Space Flight Center



Hurricane Katrina, late August 2005.

Source: EIA



Conserving Land and Water

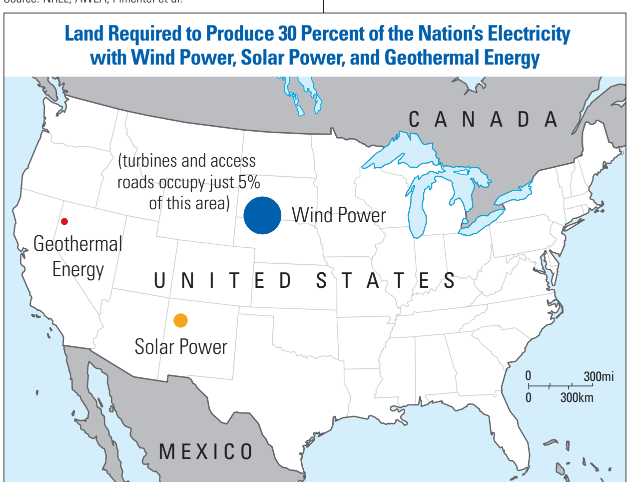
Renewable energy is commonly viewed as too land-intensive to be practical. Yet harnessing renewable energy requires less land and water than does our current energy system. Disputes over the location of renewable energy projects—particularly wind farms, such as the Cape Wind project off the Massachusetts coast—are not uncommon; they are no less so for fossil or nuclear projects. Solid regulatory procedures and strong public participation can ensure that a balance is struck between energy production and environmental and aesthetic considerations.

USDA

Missouri farmland.

Studies show that wind resources in three states—Kansas, North Dakota and Texas—could in principle meet all current U.S. electricity needs. Although wind farms appear to occupy as much as 60 acres per megawatt, depending on the terrain, the turbines and access roads actually cover under three acres per megawatt. By conservative estimates, this means that fewer than 1,400 acres are needed to produce one billion kilowatt-hours (kWh) of electricity each year. Farming and grazing can continue beneath the wind turbines, enabling farmers and ranchers to supplement their incomes with payments for green power production. Moreover, the Great Plains, where most of the best wind resource is located, is one of the least densely populated parts of the country.

Source: NREL, AWEA, Pimentel et al.



Geothermal electricity is estimated to need just 74 acres of land to generate one billion kWh of electricity annually, enough to power nearly 94,000 American homes. By contrast, coal-fired power requires 900 acres per billion kWh generated annually—most of it for mining and waste disposal. The geothermal plant can go on producing electricity on the same land for a century or more, as can wind farms, while a coal plant depends on mining hundreds of additional acres each year.

Solar power plants that concentrate sunlight in desert areas require 2,540 acres per billion kWh. On a lifecycle basis, this is less land than a comparable coal or hydropower plant requires, and because most deserts are sparsely populated, there is plenty of room for solar power plants. A little over 4,000 square miles—equivalent to 3.4 percent of the land in New Mexico—would be sufficient to produce 30 percent of the country's electricity.

In addition, sunlight can be used to produce power without using any land at all, simply by installing solar cells on the available roofs and walls of U.S. buildings. It is estimated that the nation has 6,270 square miles of roof area and 2,350 square miles of façades that are suitable for harnessing solar power. Mounting solar panels on just half of this area could supply nearly 30% of U.S. electricity.

Solar and wind power require virtually no water to operate. Large fossil and nuclear plants, in contrast, need enormous quantities of water for cooling and ongoing maintenance. According to the Union of Concerned Scientists, a typical 500-MW coal plant takes in 2.2 billion gallons of water—enough for a city of 250,000 people—each year simply to produce steam to drive its turbines.

Crops grown for biofuels are the most land- and water-intensive of the renewable energy sources. In 2005, about 12 percent of the nation's corn crop (covering 11 million acres of farmland) was used to produce four billion gallons of ethanol—which equates to about 2 percent of annual U.S. gasoline consumption. For bioenergy to make a much larger contribution to the energy economy, the industry will have to accelerate the development of new feedstocks, agricultural practices, and technologies that are more land and water efficient. Already, the efficiency of biofuels production has increased significantly.

Energy Efficiency

Improving energy efficiency represents the most immediate and often the most cost-effective way to reduce oil dependence, improve energy security, and reduce the health and environmental impact of our energy system. By reducing the total energy requirements of the U.S. economy, improved energy efficiency will make increased reliance on renewable energy sources more practical and affordable.

Energy efficiency has played a critical role in the U.S. energy supply in recent decades, reducing total energy use per dollar of gross national product (GNP) by 49 percent since the 1970s. Compared to a 1973 baseline, America now saves more energy than it produces from any single source, including oil. Efficiency improvements stabilize energy prices by reducing demand, while also delivering the same services we value—whether hot showers or cold drinks—at lower cost.

The potential for additional energy savings is vast: U.S. energy use per dollar of GNP is nearly double that of other industrial countries. More than two-thirds of the fossil fuels consumed are lost as waste heat—in power plants and motor vehicles.

The fuel economy of new U.S. motor vehicles advanced rapidly, from 14 miles per gallon in the mid-1970s to 21 miles per gallon in 1982, driven by rising fuel prices and government-mandated fuel economy standards. But in 2006, new U.S. vehicles still averaged just 21 miles per gallon; for over two decades, automakers have put most of their engineering efforts into building larger vehicles with more powerful engines, offsetting the potential fuel economy gains from new technologies.

The time is ripe for another great leap in vehicle efficiency. New technologies such as hybrid drive trains, clean-burning diesel engines, continuously variable transmissions, and lightweight materials could allow vehicle fuel economy to double over the next two decades.

Significant efficiency gains are also possible in the electricity sector. Americans spend $200 billion annually on electricity, but current demand could be halved with cost-effective technologies already available on the market. Furthermore, decreasing electricity demand reduces the need for new, large power plants, allowing smaller, distributed, renewable generation to play a greater role in meeting our energy needs.

Past experience demonstrates that strong government policies can spur the private sector to invest in efficiency improvements. Since national home appliance efficiency standards were enacted in 1987, manufacturers have achieved major savings in appliance energy use. Refrigerator efficiency nearly tripled between 1972 and 1999, and dishwasher efficiency has more than doubled in the last eight years.

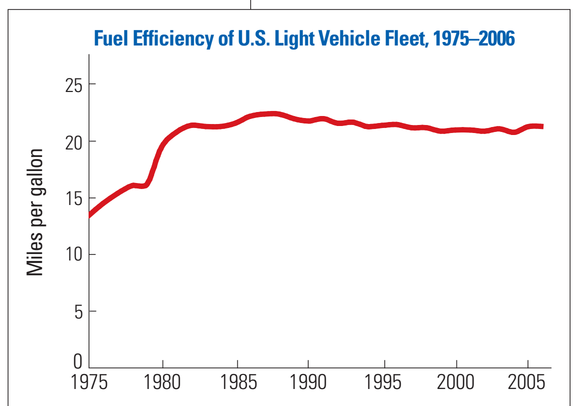
California's "Flex Your Power" campaign, enacted in response to the state's 2001 energy crisis, immediately reduced power demand by 5,000 megawatts by replacing millions of standard light bulbs with compact fluorescent lights (CFLs), installing light-emitting diode (LED) traffic lights, and replacing inefficient appliances. Because of robust efficiency policies, California has the lowest per capita energy consumption in the nation, without sacrificing comfort or valued services.

Technologies available today could increase appliance efficiency by at least an additional 33 percent over the next decade, and further improvements in dryers, televisions, lighting, and standby power consumption could avoid more than half of the projected growth in demand in the industrial world by 2030.

The integration of efficiency with renewable energy maximizes the benefits of both. For example, the correct building orientation can save up to 20 percent of heating costs; those savings can jump to 75 percent when renewable energy and appropriate insulation are integrated into the building.

A national commitment to improved efficiency can transition the U.S. energy economy in ways that will yield dividends for all Americans.

Source: DOT



EPA

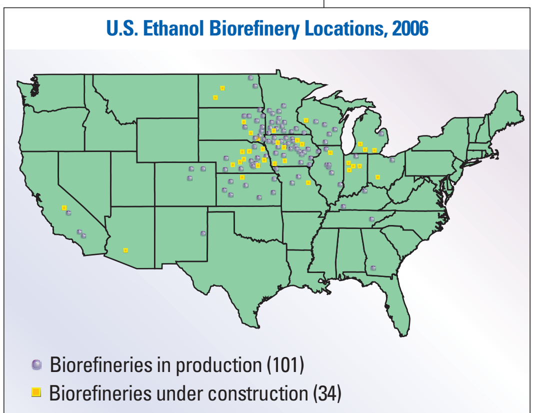
U.S. EPA's energy efficiency label.

BIOFUELS

Liquid fuels derived from crops and agricultural wastes are poised to play a large role in meeting U.S. tranportation energy needs. In addition to burning more cleanly than conventional fuels, biofuels are renewable and can be produced in every U.S. state. And, more than any other renewable energy source, biofuels can reduce dependence on imported oil, the vast majority of which is used for transportation.

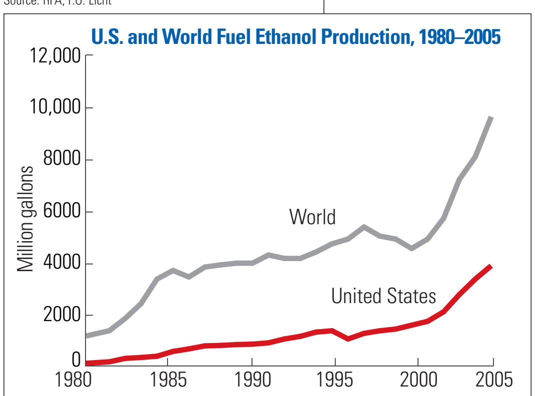
Production of biofuels also creates jobs and income in rural communities. A typical 40 million gallon per-year ethanol plant can provide a one-time boost of $140 million to the local economy. Once built, the plant increases annual direct spending in the community while providing jobs throughout the economy.

Source: RFA



Ethanol—a form of alcohol—is the predominant biofuel in use today. The United States and Brazil together produce about 90 percent of global fuel ethanol. Sugar cane-based ethanol accounts for approximately 40 percent of Brazil's non-diesel automotive fuel. In 2006, the United States passed Brazil to become the world's largest producer.

Source: RFA, F.O. Licht



America's reliance on ethanol has grown rapidly in recent years, and in 2005, ethanol provided just over 2 percent of U.S. motor vehicle fuel. While higher shares are used in the Midwestern grain-producing states where the industry is centered, ethanol production and use are expanding across the nation.

U.S. ethanol production doubled between 2000 and 2005, reaching nearly four billion gallons annually. Currently, most U.S. fuel ethanol is made from corn, the country's largest crop, ensuring a strong basis of support among U.S. farmers and agricultural processors. Other feedstock include sorghum, brewery wastes, and cheese whey.

Ethanol can be blended at low concentrations as a fuel oxygenate and has been the principal replacement for MTBE (a fuel additive that is being phased out because it is a suspected carcinogen). As of early 2006, ethanol was mixed into at least 30 percent of U.S. gasoline. The most common blend is 10 percent ethanol, known as E10, which can successfully fuel all types of vehicles and engines that require gasoline. Ethanol is also used in higher concentrations up to E85 in a new generation of "flexible-fuel" vehicles that have slight engine modifications.

Compared with ethanol, biodiesel is used on a far smaller scale. But it has recently become the country's fastest growing fuel: in 2005, the United States produced about 75 million gallons, up from 500,000 in 1999.

Biodiesel consists of bio-esters that are typically derived from vegetable oils. Although a wide variety of crops can be used, soybeans represent the predominant feedstock in the United States; canola oil and limited quantities of animal tallow and recycled vegetable oils and fats (often gathered from food processors and restaurants) are also used.

Biodiesel can be blended with ordinary diesel fuel at any concentration. Most diesel vehicles can run on blends of up to 20 percent with few or no modifications, and a few engine warrantees allow for use of 100-percent biodiesel. More than 600 vehicle fleets, ranging from school buses to National Park Service vehicles, now use biodiesel. The U.S. Navy, the largest diesel user in the world, has begun processing its used cooking oil into cleaner-burning biodiesel.

To promote the sale of biofuels, the federal government and several states offer excise tax credits for biofuel blends. Domestically produced ethanol, for example, receives a 51 cent per gallon federal subsidy. And biofuels are becoming more competitive as production costs fall and oil prices rise. According to the

International Energy Agency (IEA), ethanol from corn is cost-competitive with gasoline in the United States (even without subsidies, and accounting for ethanol's lower energy density) when the price of oil is above $45 per barrel—well below oil's price in mid-2006.

Biodiesel costs vary, depending on factors such as feedstock and production methods, but the IEA estimates that it is competitive with oil at about $65 per barrel. Costs must continue to fall, however, if biodiesel is to be used widely.

Substantial cost reductions are possible with improvements in manufacturing and scale economies. Studies show that a tripling of ethanol plant size can result in a 40 percent reduction in unit cost. While a typical new ethanol plant once had a capacity of 40 million gallons per year, many plants now under construction can produce 100 million gallons annually.

Biofuels have the potential to reduce many environmental problems associated with transportation, but they can exacerbate others if not developed carefully. The fuels are essentially a means for converting the sun's energy into liquid form through photosynthesis. Yet one of the major concerns raised about them is their net energy balance—i.e., whether the energy contained in these biofuels exceeds the energy (particularly from fossil fuels) required to make them. Thanks to technological advances throughout the production process, all of today's biofuels have a positive fossil energy balance. If bioenergy is increasingly used for feedstock processing and refining as well, the balance sheet tips further in biofuels' favor.

There is also concern that, depending on the feedstock used and how it is grown and processed, biofuels can negatively affect soil and water quality, local ecosystems, and even the global climate. For example, if biofuels are produced from low-yielding crops, grown with heavy inputs of fossil energy on previously wild grasslands or forests, and/or processed into fuel using fossil energy, they have the potential to generate as much greenhouse gas emissions as petroleum fuels do, or more. However, if sustainable feedstock is used, and it is cultivated in the right way, biofuel crops can actually sequester carbon in the soil, helping to reduce the amount in the atmosphere while also reducing soil erosion and runoff and providing valuable habitat for wildlife.

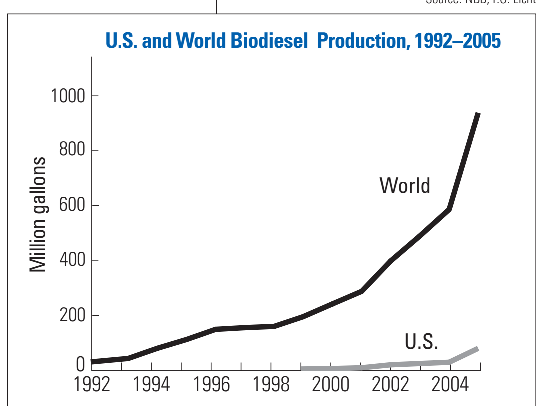
Conventional biofuels will be limited by their land requirements: producing half of U.S. automotive fuel from corn-based ethanol, for example, would require 80 percent of the country's cropland. Thus, large-scale reliance on ethanol fuel will require new conversion technologies and feedstock. Much attention has been focused on enzymes that convert plant cellulose into ethanol. Because cellulose-derived ethanol is made from the non-food portions of plants, it greatly expands the potential scale while reducing competition with food supplies. According to a joint study by the U.S. Departments of Agriculture and Energy, the nation has enough biomass resources to sustainably meet well over one-third of current U.S. petroleum needs if cellulosic technologies and resources are employed.

Years of research on enzymes that break down the cellulose in plants are nearing commercial production. Iogen Corporation, based in Ottawa, Canada, is already operating a small facility that can produce up to three million liters (about 793,000 gallons) of cellulosic ethanol annually; plans are under way for a full-scale commercial plant.

NREL

Triple biofuels pump.

Source: NBB, F.O. Licht



Biopower

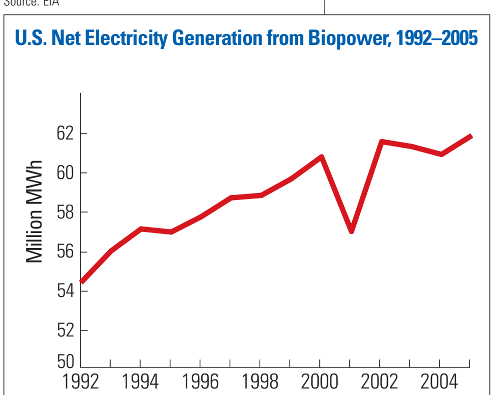
The same homegrown resources that can fuel America's vehicles can heat and power our industries, businesses, and homes. Biopower is the process of using organic matter from America's fields, forests, and landfills to generate electricity. It is the nation's largest non-hydropower source of renewable electricity. Biopower currently provides only about 2 percent of U.S. electricity, but it has the potential to meet a much larger share of power demand while reducing pollution and revitalizing rural communities.

America's biomass resources range from agricultural and forestry residues, to animal waste, to fast-growing plants grown solely for energy production. Landfills can also be tapped, by capturing methane from biodegrading organic wastes before it escapes to the atmosphere. Biomass can be burned directly to produce steam, which turns a turbine to generate power; it can be co-fired with fossil fuels; and it can be gasified to produce steam and electricity, or for use in microturbines or fuel cells. Today, most biopower is used by the forest products industries, which produce steam and power with process residues.

Jeff Vanuga, USDA, NRCS

Inspecting switchgrass field, Manhattan, Kansas.

Source: EIA



More than 100 U.S. coal-fired power plants are now burning biomass together with coal. Experience has shown that biomass can be substituted for up to 2–5 percent of coal at very low incremental cost; higher rates—up to 15 percent biomass—are possible with moderate plant upgrades.

According to the Washington Department of Ecology, the state produces enough biomass to generate over 15.5 billion kWh of electricity, or almost half of Washington's residential power consumption.

Growing energy crops for biopower poses the same environmental concerns associated with biofuels. Burning biomass in power plants releases particles that can affect human health, as fossil fuel burning does, but pollution control technologies can remove these particles from the smokestack. When burned with coal, biomass can significantly reduce emissions of sulfur dioxide, carbon dioxide (CO_2), and other greenhouse gases (GHGs). Burning biomass destined for landfills also reduces the amount of organic waste that would ultimately decompose and release methane, a GHG that is 21 times more potent than CO_2.

Capturing methane from the decomposition of organic matter found in landfills, sewage treatment plants, and livestock facilities provides premium fuel while reducing the amount of waste that must be disposed of. Using anaerobic digesters at all U.S. farms where they would be economical could avoid emission of an estimated 426,000 metric tons of methane annually. This practice is starting to catch hold in large hog, poultry, and cattle operations, driven by the need to control emissions and by the lure of selling lucrative energy. Central Vermont Public Service sells electricity produced from farm waste directly to consumers, and will soon generate enough power for 1,400 Vermont homes.

Biopower can provide baseload electricity, and plants can be located close to the point of demand, reducing the need for expensive upgrades to the power grid and minimizing transmission losses. In addition, biopower can generate up to 20 times more local jobs than natural gas-fired power plants do. Facilities can range in size from small farm-based operations to much larger plants.

As with other renewable technologies, inconsistent availability of subsidies has hampered industry development. In addition, the permitting process is often time-consuming and expensive, and a lack of national grid-connection standards often complicates development. These policies must be reformed if biopower is to fulfill its promise.

Geothermal Energy

Geothermal resources represent a potentially vast supply of domestic energy, with the ability to provide dependable, baseload power at stable cost. Geothermal energy flows from the Earth's mantle, reaching the surface in the form of hot springs, geysers, and volcanoes. Geothermal systems are designed to bring underground heat to the surface and convert it to useful forms of energy.

Low-to-moderate heat resources can be tapped for a number of direct uses, including space heating, industrial processes, and greenhouses. All areas of the United States have nearly constant ground temperatures suitable for geothermal heat pumps, which use the earth or groundwater as a heat source in winter and a heat sink in summer to regulate indoor temperatures. More than 600,000 geothermal heat pumps are operating today, and the market is growing at an annual rate of 15 percent. The city of Boise, Idaho, developed four direct-use district systems that together heat 366 buildings, including the state capitol.

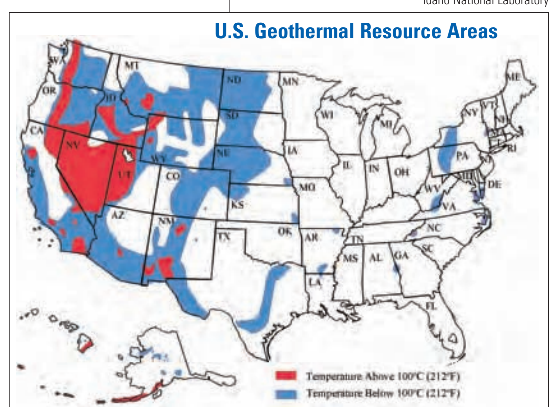
The highest-temperature resources can be used for power generation. Hydrothermal systems, which transfer the geothermal resource to power stations via steam, are the primary technology in use today, but geopressured, hot dry rock, and magma technologies are currently under development.

By the end of 2005, geothermal electric capacity totaled 8,932 MW in 24 countries, and produced about 57 billion kWh of power annually. The United States leads the world in geothermal electric and thermal heat installed capacity, with more than 2,828 MW of power capacity operating in four states: California, Hawaii, Nevada, and Utah. Each year, U.S. geothermal energy displaces the energy equivalent of more than 60 million barrels of oil, prevents the emission of 22 million tons of CO_2, and produces \$1.5 billion worth of electricity—enough to meet the power needs of about four million people.

The largest barriers to geothermal development have been the initial cost and risk of proving new resources. Investors may be deterred because only one in five exploratory wells is successful. But improved technology is reducing the risks and costs of exploration. Together with the inclusion of geothermal energy in the 2005 federal production tax credit and state renewable standards, advances are spurring renewed interest in geothermal power projects. Projects now planned or under development in nine western U.S. states could nearly double current capacity.

The Geothermal Energy Association estimates that by 2025, U.S. geothermal resources could provide more than 30,000 MW of power, enough to meet 6 percent of today's electricity demand. New development could create 130,000 new jobs and add more than \$70 billion of investment to the economy. But half of this development potential depends on continued federal R&D.

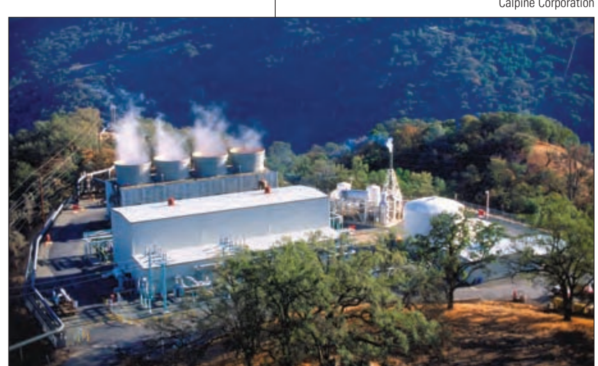
Idaho National Laboratory



Extracting geothermal energy is nearly emissions free, but small amounts of hydrogen sulfide, CO_2, and other gases can be released. New technologies are able to reduce these emissions substantially, if not eliminate them. CO_2 emissions from geothermal power plants are a fraction of the emissions from equivalent fossil fuel power plants. The land and freshwater requirements for geothermal power plants are among the lowest for any generating technology, and district heating systems and geothermal heat pumps are easily integrated into communities with little visual impact.

Advanced technologies can convert lower-temperature resources into electricity, allowing the country to harness a much larger fraction of its geothermal resources.

Calpine Corporation



The Geysers, Northern California.

Power from the Wind

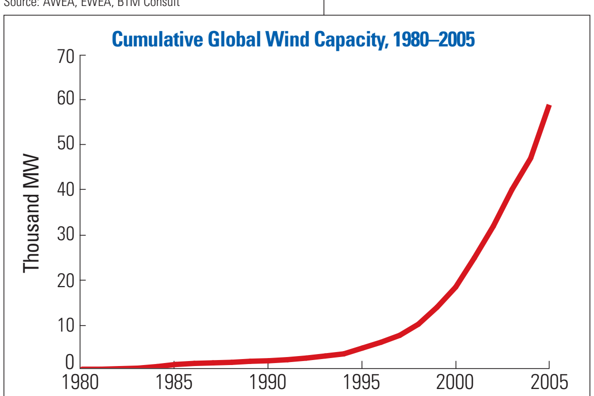
The wind that sweeps across America is one of the country's most abundant energy resources. About one-fourth of the total land area of the United States has winds powerful enough to generate electricity as cheaply as natural gas or coal at today's prices. According to government-sponsored studies, the wind resources of Kansas, North Dakota, and Texas alone are in principle sufficient to provide all the electricity the nation currently uses.

GE Wind Energy

Trent Mesa Wind Power Facility (150 MW), Sweetwater, Texas.

Although wind power presently provides less than 1 percent of U.S. electricity, it is poised to expand dramatically. Wind energy technology has advanced steadily over the past two decades. Average turbine size has increased from less than 100 kW in the early 1980s to more than 1,200 kW today, with machines up to 5,000 kW under development. The largest machines have blade spans over 300 feet, compared with roughly 200 feet for a typical jumbo jet.

Source: AWEA, EWEA, BTM Consult



Additional advances, from lighter and more flexible blades to sophisticated computer controls, variable speed operation, and direct-drive generators, have driven costs down to the point where wind farms on good sites can generate electricity for 3–5 cents per kilowatt-hour. These advances, together with sharp increases in natural gas prices, have made wind power the least expensive source of new electricity in many regions.

Meanwhile, the global wind power market is advancing rapidly. Installations increased from 1,290 MW in 1995 to 11,770 MW in 2005. Today, private sector R&D dwarfs government investment, and the wind power industry is in a race to drive costs down even further in the coming years.

Global turbine manufacturing is dominated by companies based in the largest markets: Germany, Spain, and Denmark. However, the United States is still in the game: the world's largest power-generation company, General Electric, entered the wind business in 2002 and has become one of the world's top turbine producers. On the project development side, the U.S. industry is dominated by a large, diversified power company, Florida Power and Light, which develops and owns wind farms throughout the country.

The United States led the world in wind energy capacity in the 1980s, but abrupt changes in federal and state policies led to market collapse. Since the 1990s, a new federal tax credit, combined with an increasing number of supportive state policies, has led to a growing but episodic market. Short-term extensions of the federal tax credit, often after long delays, have caused wild swings in new installations—from about 400 MW in 2002 and 2004, to approximately 1,700 MW of new capacity in 2001 and 2003—which have discouraged the industry from making long-term investments.

Extension of the credit through 2007 helped drive another upswing in 2005: the United States installed a record 2,431 MW, adding more wind power capacity than any other country for the first time in over a decade. Wind farms were the country's second largest source of new generating capacity built in 2005, after natural gas-fired plants. By the end of that year, the nation had enough cumulative wind capacity to meet the needs of 2.3 million U.S. households, and trailed only Germany and Spain in total installations. The industry expects more record-setting years in 2006 and 2007.

In Denmark and some areas of Germany and Spain, wind meets more than 20 percent of electricity needs. The key to success in these countries is laws that provide renewable power producers with long-term power purchase agreements at prices sufficient to cover costs. By maintaining a consistent set of policies, and by gradually lowering the purchase price as technology improves, European countries have nurtured a wind power industry that is already cost-competitive with new gas-fired power plants in most countries.

Wind resources in the United States are far more plentiful than in Europe. The U.S. wind resource is well distributed across the country, with the most abundant winds in the Great Plains, a region that has been described as a potential "Persian Gulf" of wind power. And the Department of Energy estimates that the offshore wind resource within 5–50 nautical miles of the U.S. coastline could support about 900,000 MW of wind generating capacity—an amount approaching total current U.S. electric capacity. Although much of this resource will likely remain undeveloped because of environmental concerns and competing uses, the nation's offshore wind energy potential is enormous, and much of it lies near major urban load centers.

More fully tapping that wind will require new policies to provide more-ready access to existing high-voltage transmission lines, and in the longer run, the expansion of transmission capacity to allow Great Plains wind power to reach cities in the Midwest and on the West Coast. In the meantime, sizable wind power projects are planned or being developed in states from California to New York, Texas, and Montana. The country's largest offshore wind project (500 MW) has been proposed off the Texas coast in the Gulf of Mexico.

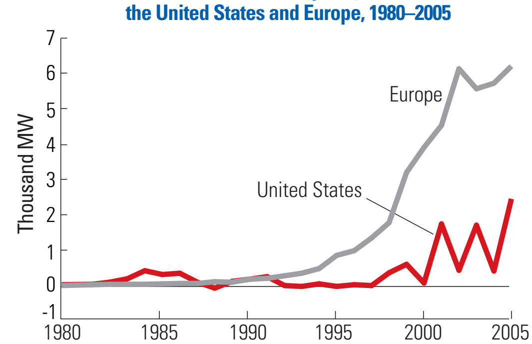
As with all energy technologies, there are environmental costs associated with wind power, which have generated opposition from local residents concerned about the rapid proliferation of new projects in many parts of the country. The greatest controversy has arisen from the fact that wind turbines in some locations have killed significant numbers of birds and bats. Yet housecats, vehicles, cell phone towers, buildings, and habitat loss pose far greater hazards to birds, and progress has been made in reducing bird strikes through technological changes, such as slower rotating speeds, and careful project siting.

On balance, the environmental, economic, and social benefits of wind power outweigh the costs. During 2005, wind turbines operating in the United States offset the emission of 3.5 million tons of carbon dioxide, while reducing natural gas demand for power generation by 4–5 percent. Wind farms can be permitted and built far faster than conventional power plants. And by some estimates, every 100 MW of wind capacity creates 200 construction jobs, 2–5 permanent jobs, and up to $1 million in local property tax revenue.

As new wind farms come on line, a growing number of electric utility managers are learning how to integrate an intermittent resource into their power grids. These grids are designed to routinely manage variability in demand and supply. The amount of wind power capacity that can be accommodated depends on the size of the regional grid and the flexibility of other types of generation attached to it. In both Europe and North America, electric utilities have demonstrated the ability to manage wind generation that exceeds 20 percent of total capacity. Higher shares of wind power will be possible with modest operational adjustments and better wind forecasting.

Source: AWEA, BTM Consult, Gipe, EWEA, GWEC

Annual Wind Power Capacity Additions in the United States and Europe, 1980–2005



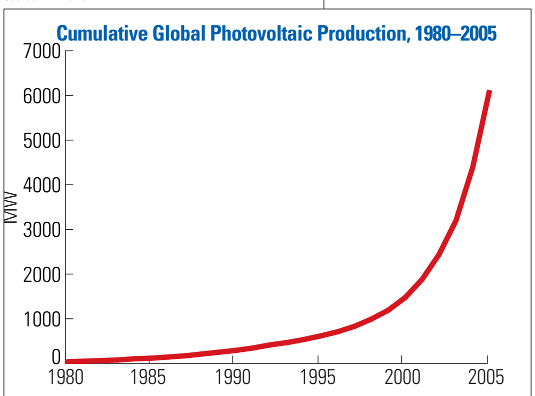
The key to achieving this potential is a strong and consistent policy framework, at both the state and federal levels. The on-again off-again tax credit for wind power and similarly intermittent state policies have undermined the stability that companies require to invest in new installations, technologies, and factories in a sustained manner.

If solid and consistent policies are implemented, wind power's contribution to the U.S. electricity supply could grow rapidly. In June 2006, the Department of Energy committed to developing an action plan with the goal of providing up to 20 percent of U.S. electricity with wind power.

Rooftop Solar Power

Solar cells (also known as photovoltaic cells, or PVs) that convert sunlight directly into electricity are one of the most revolutionary new energy technologies to be commercialized in recent decades. These devices are most often composed of crystalline silicon chips similar to those found in computers. They are adaptable to a remarkable range of uses, from handheld electronic devices to mountaintop weather stations, large desert power plants, and America's rooftops. Solar cells can produce electricity almost anywhere—the solar resource in Maine, for example, is about 75 percent of that in Los Angeles.

Source: PV News



Annual global production of solar cells has increased six-fold since 2000, exceeding 1,700 MW in 2005, and the industry plans to continue its dramatic expansion. Global grid-connected PV capacity increased 55 percent in 2005, to 3.1 gigawatts, making it the world's fastest growing source of power.

PowerLight Corporation

PV panels atop U.S. Coast Guard Building, Boston, Massachusetts.

Solar cells were originally developed for use in orbiting satellites and, until recently, were far too expensive for most earthbound energy applications. Improved manufacturing, efficiency gains, and economies of scale in production and installation have steadily lowered costs. Since 1976, prices have dropped by about 5 percent annually, and they continue to fall. New technologies under development, such as plastic solar cells, nanomaterials, and dye-sensitized solar cells, could enable the industry to leapfrog far beyond current technologies, further reducing costs while improving performance.

Solar power is already the most economical way of providing electricity in many circumstances, particularly for small-scale devices like roadside call-boxes and off-grid telecommunications installations. Such uses are important but represent relatively small markets. Major opportunities exist, however, for customers who value the security, power quality, and reliability that PV systems can provide—for emergency preparedness and security uses, for example.

Thousands of solar-powered homes have already been built in the United States—many of them in suburban neighborhoods, where excess power is fed into the electric grid, which later provides electricity for the home when the sun isn't shining. In southern California, builders and developers have begun promoting solar power as an inviting new feature. And elsewhere around the country, PVs are appearing on high-rise apartment buildings, atop urban metro stations, and on the rooftops of rural businesses.

In some locations, rooftop solar power is now competitive with peak electricity prices, which often coincide with peak sunshine. And PVs can be cheaper than other façade materials, such as granite or marble, with the added benefit of producing power.

Solar PV manufacture requires hazardous materials, including many of the chemicals and heavy metals used in the semiconductor industry. However, there are techniques and equipment to reduce the environmental and safety risks, and the industry is moving toward recycling of old solar cells.

Japan has led the solar PV industry for most of the past decade, despite having half the solar resource of California. Strong incentives from government policies—including gradually declining rebates, net metering, low-interest loans, and public education programs—boosted Japan from a minor player in the early 1990s to the world's largest producer and user of solar PV within a decade. Japan's policies drove down system costs by more than 80 percent, to the point where rooftop power is now competitive with Japanese electricity prices, which are among the world's highest.

Today, Japan remains the world's leading solar PV manufacturer, accounting for 48 percent of production in 2005, but Germany is now the leading market. High purchase prices for PV-generated electricity have been a powerful driver of German demand. Germany added an estimated 600 MW during 2005 alone—far more than cumulative U.S. installed capacity. Both Germany and Japan have reaped significant employment and economic benefits from strong policies aimed at expanding markets and driving down costs. Spain, the first country to require installation of PV in new and renovated buildings, will likely join them soon.

Rapid growth in Japan and Europe has encouraged major companies—some entering the energy industry for the first time—to step up investments in solar PV. These investors include Japan's Sharp and Kyocera companies, oil giants BP and Royal Dutch/Shell, and General Electric and Dupont in the United States.

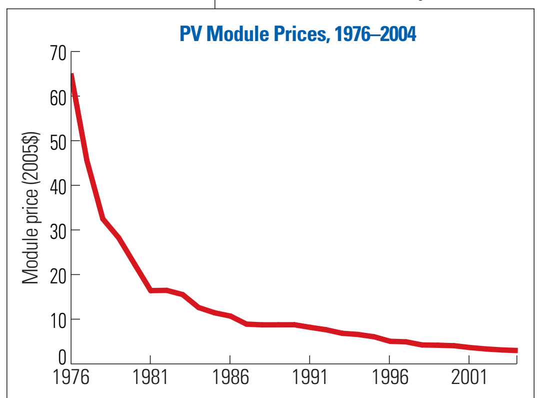
The United States is the birthplace of the solar cell industry and, as recently as 1996, U.S. producers held 44 percent of the global solar cell market. By 2005, that figure had fallen to below 9 percent as markets boomed in other parts of the world, and U.S. producers had lost much of the market at home as well. But this trend could reverse due to new state policies driving demand.

In early 2006, California state regulators approved $3.2 billion in customer rebates with the goal of installing 3,000 MW of PV on the rooftops of one million California homes, businesses, and public buildings by 2017, up from about 100 MW today. New Jersey, which offers a rebate and sales tax exemption for solar PV, has the second largest U.S. market after California.

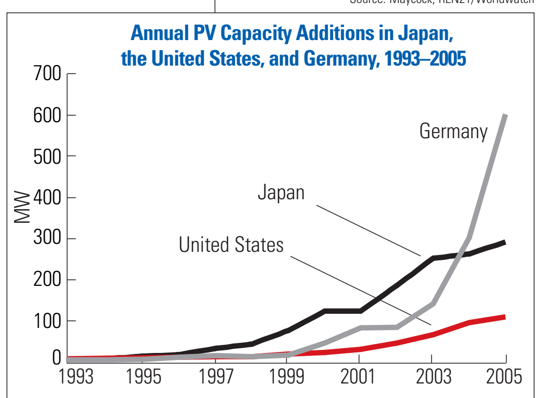
The International Energy Agency (IEA) estimates that PV installed on appropriate rooftops, facades, and building envelopes in the United States could meet about 55 percent of U.S. electricity demand. The Solar Energy Industries Association aims for PV to provide half of all new U.S. electricity generation by 2025; SEIA projects that by 2020, the PV industry could provide Americans with 130,000 new jobs.

Beyond rooftops, solar cells can replace diesel generators for water pumping on America's farms, wastewater treatment plants, and other uses. And they can produce power on a large scale in the U.S. Southwest. According to an IEA study, very-large-scale PV systems installed on just 4 percent of the world's deserts could generate enough electricity annually to meet world power demand.

Source: Strategies Unlimited, BP Solar



Source: Maycock, REN21/Worldwatch



Desert Solar Power

Large desert-based power plants concentrate the sun's energy to produce high-temperature heat for industrial processes or convert it into electricity that is available when demand is greatest. Resource calculations show that just seven states in the U.S. Southwest could provide more than 7 million MW of solar generating capacity—roughly 10 times the total U.S. generating capacity from all sources today.

Solar power facility at Kramer Junction, California.

Four concentrating solar technologies are being developed. To date, parabolic trough technology provides the best performance and lowest cost of all types of solar power plants. Nine plants, totaling 354 MW, have operated reliably in California's Mojave Desert since the mid-1980s. Dish-engine and power tower systems are in earlier stages of prototype and commercial development. Natural gas and other fuels can provide supplementary heating when the sun is inadequate, allowing solar power plants to generate electricity whenever it is needed. In addition, heat-storing technologies are being developed to extend the operating times of solar power plants.

Since the first 14 MW trough plant was installed in California in the early 1980s, generating costs have dropped from 45 cents/kWh (in 2005 dollars) to 9–12 cents/kWh (competitive with peak power). Costs are expected to drop to 4–7 cents/kWh by 2020.

Several solar power plants are now being planned in the U.S. Southwest, spurred by state requirements that a minimum share of electricity come from solar technologies. Renewed federal support and rising natural gas prices have also stoked new interest in concentrating solar power. Solargenix is constructing a 64 MW trough plant in Nevada that should be operational in early 2009. While earlier trough plants needed a 25 percent natural gas-fired backup, this plant will require only 2 percent backup. Stirling Energy Systems has signed power purchase agreements with two California utilities totaling 1,750 MW and plans to begin constructing a 1 MW pilot plant in California by the end of 2006.

Utilities in states with large solar resources (Arizona, California, Nevada, and New Mexico) are considering installation of solar dish systems as well. No commercial central receiver or tower plants have been built to date, but an 11 MW generator is under construction in Spain. According to the Western Governors' Association Solar Task Force report, within the next decade, 4,000 MW of central solar plants could be installed in the United States, generating thousands of new jobs.

For solar energy to achieve its potential, plant construction costs will have to be further reduced via technology improvements, economies of scale, and streamlined assembly techniques. Development of economic storage technologies can also lower costs significantly.

The U.S. Southwest has some of the most valuable solar resources in the world, with much of this potential close to major urban areas and on land that has few if any alternative economic uses. According to the National Renewable Energy Laboratory, a solar plant covering 10 square miles of desert would produce as much power as the Hoover Dam. Desert-based power plants could well provide a large share of the nation's commercial energy.

Concentrating Solar Technologies

Parabolic trough technologies track the sun with rows of mirrors that heat a fluid. The fluid then produces steam to drive a turbine.

Central receiver (tower) systems use large mirrors to direct the sun to a central tower, where fluid is heated to produce steam that drives a turbine. Parabolic trough and tower systems can provide large-scale, bulk power with heat storage (in the form of molten salt, or in hybrid systems that derive a small share of their power from natural gas).

Dish systems consist of a reflecting parabolic dish mirror system that concentrates sunlight onto a small area, where a receiver is heated and drives a small thermal engine.

Concentrating photovoltaic systems (CPV) use moving lenses or mirrors to track the sun and focus its light on high-efficiency silicon or multi-junction solar cells; they are potentially a lower-cost approach to utility-scale PV power. Dish and CPV systems are well suited for decentralized generation that is located close to the site of demand, or can be installed in large groups for central station power.

Solar Heating

The sun's energy could provide much of the heating and cooling for America's homes and industries. Solar water heaters, which have been used for decades, are a particularly convenient way to use the sun's energy. Simple rooftop collectors made of steel, glass, and plastic heat water, while natural gas or electricity is used for backup when the sun isn't shining.

Solar systems can be used from New England to California and are more cost-effective in Chicago than Miami, due to Chicago's higher energy prices. In some climates, solar heaters can provide up to 80 percent of a home's hot water.

Residential solar water heating systems initially cost between $1,500 and $3,500, compared to $150–$450 for electric and natural gas water heaters, but they typically pay for themselves in 4–8 years through fuel savings. Savings continue for the remaining 15–40 year life of the system. Newer systems with low-cost plastic polymers and highly efficient vacuum tubes are providing new options and lower costs.

The United States led the solar heating industry in the 1980s, but since then the almost complete elimination of government incentives, combined with falling natural gas prices, left the United States far behind. More than 1.5 million U.S. homes and businesses now use solar water heating, and their systems produce enough energy annually to offset the output of a nuclear power plant. Only about 8 percent of these systems are used for water and space heating; the rest heat swimming pools. Hawaii leads the nation in per capita use of solar water heating, thanks to utility rebate programs and the lack of natural gas, which have driven significant demand for residential systems.

Solar energy is being tapped for space heating in commercial and industrial buildings as well. Typically, a building's south-facing wall is covered with dark-colored perforated metal sheeting, which collects solar heat that is distributed into the building through conventional ductwork. Up to 80 percent of available solar radiation is converted to heat. Solar space heating systems are more expensive than water heating systems, but will become more competitive as conventional heating costs rise. And solar energy can be used for cooling via the oldest form of air conditioning technology—absorption cooling—with the same devices used to provide heat in the winter.

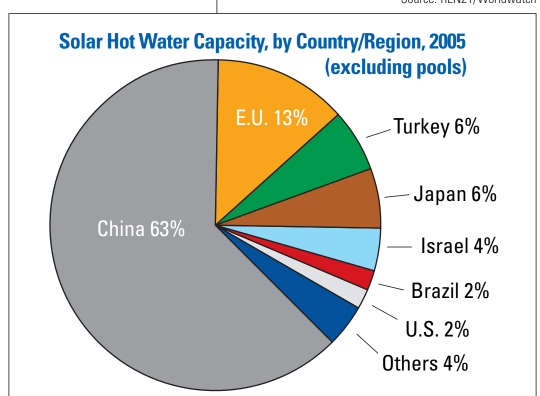
Worldwide, solar heating is booming: the global market doubled between 2000 and 2005, with the greatest increases in China and Europe. The International Energy Agency estimates that total global installations of solar heating panels for all uses amount to about 196 million square yards, enough to cover the equivalent of more than 30,000 football fields.

A Department of Energy study projects that half of residential space heating and 65–75 percent of water heating needs could be met with solar. But stronger government support at the federal, state, and local levels will be needed if the United States is to keep up with the solar heating boom in other countries.

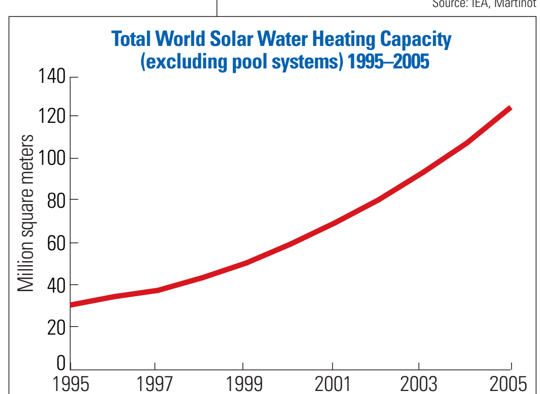
SunEarth Inc.

Solar water heating system atop a commercial buidling.

Source: REN21/Worldwatch



Source: IEA, Martinot



Hydropower

Hydropower uses the natural energy of falling and flowing water to produce electricity or mechanical energy. Water wheels were widely used to grind grain and later to run America's factories until grid-connected electricity freed industrial processes to locate away from falling water.

NREL

Tygart River, West Virginia.

Today, hydropower provides about one-fifth of the world's electricity and nearly 7 percent of U.S. power—the largest share of any renewable resource. In 2004, hydropower generated 270 billion kWh of electricity in the United States, a figure that has remained roughly constant for three decades.

Hydropower plants cost relatively little to run and can be operated and maintained by trained local staff. They generally have a long project life: equipment such as turbines can last 20–30 years, while concrete civil works can last a century or more.

Unlike most power plants, the amount of electricity generated at hydro dams can be quickly increased or decreased, giving regions that have a large portion of hydro generation—like the Pacific Northwest—added flexibility in how they operate their power systems. Hydropower can help maintain grid stability and can be called up when other power sources fail. Flexibility allows for a sizable share of intermittent renewable capacity from solar or wind energy—which can be easily backed up with hydropower.

In principle, U.S. hydropower generation could be increased significantly. The Department of Energy (DOE) reports that hydropower could double its current contribution of more than 78,000 MW. According to DOE, 21,000 MW of capacity could be added simply by improving existing projects and installing generators at dams that do not have them. Of the 80,000 dams in the United States, only 3 percent are used to generate electricity.

Despite this potential, the industry has experienced sluggish growth over the past decade. As with other renewables, upfront capital costs are high. The licensing process can be time consuming and costly, and the lack of tax incentives for hydropower has served as a disincentive to growth.

In the past, extensive damming of rivers has destroyed unique landscapes and eliminated fish habitats. Critics argue that habitat alteration, disruption of fish migrations, trapping of sediment, displacement of communities, and greenhouse gas emissions from rotting organic material are among the possibly irreversible impacts of hydropower. The industry is pursuing a variety of measures to reduce such impacts.

The vast majority of the nation's hydropower comes from large-scale facilities, but a significant share of U.S. hydro plants today are micro-scale (up to 100 kW) or small-scale systems (100 kW to 30 MW). Rather than using a large dam and storage reservoir, micro- and small-scale projects generally use "run-of-river" designs that produce electricity by diverting only part of a stream. Most consist of small turbines that rely on water pressure or velocity to generate power.

Small hydro facilities often have difficulty gaining affordable grid connections, and power purchase agreements with utilities are generally required for independent power producers to operate such systems. And even small hydro is hindered by the perception that it can adversely affect fishing. But environmental impacts can be curtailed through good system design and appropriate construction and operating practices. Small-scale hydro systems cause little change in stream channel and flow, and thus have minimal impact on water quality, fish migration, and surrounding habitat.

Source: EIA

Hydropower Generating Capacity in Top 10 U.S. States, 2005

Washington	21,010 MW
California	13,475 MW
Oregon	8,261 MW
New York	5,659 MW
Tennessee	3,950 MW
South Carolina	3,455 MW
Georgia	3,313 MW
Virginia	3,091 MW
Alabama	2,961 MW
Arizona	2,890 MW

Marine Energy

Just off America's coastlines are energy resources with the potential to contribute substantially to the U.S. economy. Oceans cover roughly 70 percent of the Earth's surface and collect and store a tremendous amount of heat from the sun as well as mechanical energy in the form of tides and waves. Seawater is about 800 times as dense as air, so even slow velocities of water contain enormous quantities of energy. Globally, wave and ocean thermal energy individually are estimated to be of the same order of magnitude as present world energy demand, while energy from tides and currents is capable of making a roughly 10 percent contribution.

From the Middle Ages until the Industrial Revolution, tide mills were common sights along the coasts of western Europe. Today, tidal power is the most commercially advanced of the ocean energy technologies, and recent innovations in tidal power technologies avoid the environmental impacts of damming bays or estuaries. Other forms of modern marine energy conversion are still at the early stages of development, with a variety of technology types being explored. Engineers consider these technologies to be 10–20 years behind wind power, but to be coming of age rapidly.

Small-scale wave and tidal current projects are now being installed around the world. Europe, Australia, and Japan are further along in development of these sources than the United States, primarily because of more extensive government support. As a result, major private investors such as Electricité de France are now involved in prototype projects.

Recently, a few U.S. states, cities, and electric utilities have begun to fund research and commit to purchasing electricity from demonstration plants. Small projects have been proposed for the cities of New York and San Francisco and off the coasts of Massachusetts, Washington, Oregon, and Hawaii. A tidal project planned for New York's East River could eventually provide power for 8,000 homes.

While ocean thermal energy and current energy are concentrated in specific areas (Hawaii for ocean thermal and Florida for current energy), most coastal states could tap their wave and tidal energy. Ocean energy resources are generally more consistent than wind or solar energy, and offer significant potential for job creation in coastal communities where shipbuilding and commercial fishing are in decline. The Electric Power Research Institute (EPRI) estimates that U.S. near-shore wave resources alone could generate some 2.3 trillion kWh of electricity annually, or more than eight times the yearly output from U.S. hydropower dams.

U.S. ocean energy developers face significant regulatory uncertainty when it comes to siting and licensing projects, which makes it difficult to obtain financing. A one-megawatt wave energy project off the coast of Washington state has faced more licensing hurdles than those confronted by most large-scale fossil fuel plants because of jurisdictional uncertainty.

Marine energy is not yet economically competitive with conventional energy, but it is already attractive for islands and isolated coastal communities that are off the grid. A recent EPRI report concluded that electricity generation from wave power, for example, could be economically feasible in the near future. Ocean Power Technologies, the world's first publicly traded wave power company, claims that total costs will be 3–4 cents/kWh for 100 MW systems.

Marine Energy Technology Options

Tidal Power Tidal power technologies harness energy from the rise and fall of the tides, using dams to trap water in a bay or estuary at high tide. When the ocean level outside the dam has fallen enough to create a sufficient pressure difference, the trapped water is returned to the sea through conventional hydroelectric turbines. Tidal power has the advantage of being fairly predictable. Such plants have been in use for decades in Canada, China, Russia, and France (where the largest system, 240 MW, is operating).

Ocean Current Power Ocean currents, such as the Gulf Stream off the U.S. East Coast, are in effect massive rivers in the world's oceans, and they represent enormous quantities of energy. Technologies that harness these energy flows look like undersea wind turbines. A handful of prototype turbines now operate in the United Kingdom and Norway, and at least two U.S. companies are developing ocean current turbines. Ocean current energy is very site-specific (in the United States, only the eastern coast of Florida has significant potential), but it has the advantage of being highly predictable.

Wave Energy Some wave energy devices consist of a floating buoy or hinged-raft that uses pistons to pump fluid through hydraulic motors. Oscillating water column devices use the up-and-down motion of the water surface in a "capture chamber" to alternately force air out and draw it in through a pneumatic turbine. Only a few wave energy devices have been demonstrated in the ocean for more than a few months, mainly in Europe and Japan. The greatest potential is close to coastlines, often in areas with high population densities, such as the U.S. West Coast.

Ocean Thermal Energy Conversion (OTEC) OTEC harnesses the temperature difference between sun-warmed surface waters of the tropical ocean and deep water at near-freezing temperatures. Warm water is used to vaporize a working fluid, which expands through a turbine and is then condensed by the deep, cold-water, enabling continuous flow of vapor through the turbine to generate electricity or to split seawater into hydrogen. In the tropics, the required temperature difference is nearly constant, so OTEC can provide baseload power. Small "proof-of-concept" experiments have been conducted in Hawaii and Japan, but no full-scale OTEC plants have been built.

American Energy Policy Agenda

America needs a fresh and innovative approach to energy policy. Today's energy system has been shaped by a century of government subsidies and regulatory support. Even today, fossil fuels receive billions of dollars of federal subsidies each year, while the health, environmental, and security costs of those fuels are paid by society at large—and are not reflected in the market price of energy.

Over the past three decades, governments in the United States and abroad have experimented with a variety of policies to promote renewable energy and improve energy efficiency. Although frequent shifts in government support have hindered development, policymakers can learn much from these experiences, which will help to build a policy framework that allows renewable energy to flourish.

Across the United States and around the world, there is one clear lesson from past policy experiments: wherever renewable energy industries have emerged, government policy reforms have played a central role. The key to a bright American energy future and a new wave of economic activity and innovation is a robust partnership between government and the private sector—providing incentives to jumpstart the new energy industries while minimizing the cost to American taxpayers.

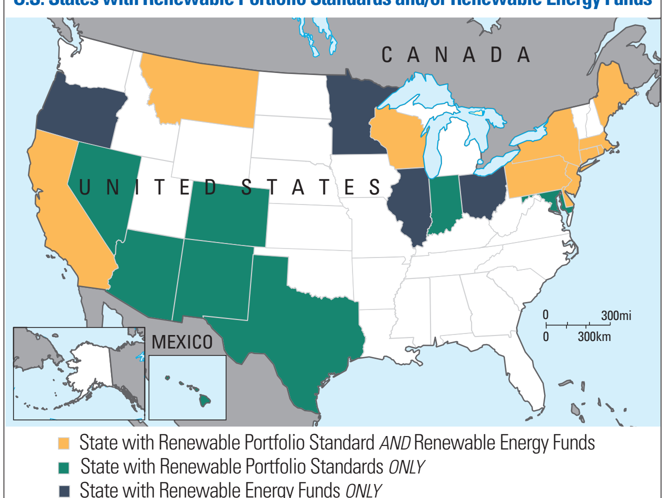
To fully utilize America's renewable energy resources, policies should be enacted that:

Ruth Tsang, Stock.xchng

U.S. Capitol Building, Washington, D.C.

Source: DSIRE

U.S. States with Renewable Portfolio Standards and/or Renewable Energy Funds



- *Establish a consistent, predictable, and long-term framework of rules and incentives.* Renewable resource developers, like other capital financers, need certainty to make informed investments.
- *Create performance-based incentives.* To leverage the most energy from each dollar of public investment, incentives must be based on the amount of energy generated or saved, rather than the cost of installation. In addition, incentives should evolve over time in a predictable manner to spur investment and innovation.
- *Incorporate external costs and benefits into energy pricing, especially the introduction of greenhouse gas cap-and-trade.* The full security, economic, and environmental costs of fossil fuels, and the full benefits of renewables, are not reflected in their prices. Including the full cost associated with energy generation in pricing would encourage producers and consumers to adjust their behavior toward more sustainable practices.
- *Reduce subsidies for fossil fuels.* In recognition of the maturity of the fossil fuel industries and the public benefit of reducing fossil fuel use, subsidies to these industries should be reduced or eliminated.
- *Enact complementary policies for energy efficiency.* Renewable energy and energy efficiency go hand in hand. Policies to increase energy efficiency—including stronger building codes, increased vehicle fuel economy standards, and advanced efficiency standards for appliances—should complement policies designed to expand renewable energy production.
- *Involve stakeholders at all levels.* Stakeholder involvement should be encouraged at all levels of policymaking and implementation, from policy design to project ownership. Successful development of resources requires the involvement of all affected groups.
- *Promote cooperation regionally and internationally.* Increasing reliance on renewable resources also increases the need for greater regional cooperation to ensure reliability. The electricity sector is already moving in this direction, and policies to continue this regional integration should be supported. The United States should actively cooperate

with and learn from the many countries that are developing renewable energy and the policies to support it.

Although numerous policies meet these overarching principles, the following specific recommendations should be established immediately. Governments, at all appropriate levels, should:

- *Establish clear and long-term goals and targets for renewable energy use and energy efficiency gains.* State and local governments should be allowed to establish more ambitious targets beyond federal requirements.
- *Provide long-term, low interest loans and bonds to address high upfront costs and reduce risk.* Renewable energy sources often require higher capital expenditures and have different depreciation timeframes than traditional energy sources. Government-backed financial instruments can help bridge the gap between traditional energy financing as investors adjust to the new investment requirements of renewable energy.
- *Use government purchasing power together with the private sector to build large, aggregated markets for renewable energy.*

Policies needed in the electricity and heating sectors include:

- *Ensure fair market access and pricing for renewable electricity.* Several countries have significantly increased their share of renewable energy by the use of "feed-in" laws requiring that a fixed price be paid for each unit of renewable electricity produced for the grid. Several U.S. states have enacted or are considering similar mechanisms. Standardized interconnection procedures are also needed.
- *Implement siting regulations to address environmental, aesthetic, and other concerns and to reduce uncertainty for stakeholders.* Like any energy project, renewable energy resources must be developed in an environmentally responsible way; currently, developers are confronted by a patchwork of regulations and guidelines that can change rapidly. The siting process should be fair and consistent.
- *Enact "high-performance" building codes to improve efficiency and increase the share of energy provided from decentralized renewable sources.* California and other states and cities have demonstrated the power of rigorous building codes to increase building efficiency and promote renewable energy. Governments at all levels should commit to meeting the highest standards in all new buildings and to retrofitting older buildings during scheduled renovations.

Policies needed in the transportation sector include:

- *Require most new vehicles sold to be flexible-fuel vehicles.* Together with increased efficiency, raising the number of vehicles that can run on high blends of biofuels is crucial to reducing our oil use.
- *Establish quotas for biofuels that gradually increase their share of transport fuel while increasing the share derived from advanced techniques and sources.* The early success of the Renewable Fuel Standard in increasing production and investment in biofuels must be nurtured by gradually raising the target levels. Added requirements and incentives should be integrated into the RFS to spur the production of biofuels from advanced technologies that reduce greenhouse gas emissions beyond current production techniques.
- *Ensure the creation of fueling infrastructure.* Flex-fuel vehicles will fulfill their potential only when drivers can easily fill their tanks on high blends of biofuels. Policies are required to ensure that the number of biofuel pumps keeps up with the production of biofuels and flex-fuel vehicles.

Feed-in Laws Explained

In contrast to Renewable Portfolio Standards (RPS), which set a target quantity of electricity from renewable energy, feed-in laws set a price and allow the market to determine quantity. Any company or individual who meets the technical and legal requirements can sell renewable electricity into the grid and receive a long-term, guaranteed price. Prices are generally set above conventional power costs, reflecting renewable energy's societal benefits.

To date, pricing laws have consistently been the most effective regulatory framework for advancing renewable electricity, propelling Germany and other European countries to market dominance. The combination of guaranteed demand and long-term minimum payments has reduced the uncertainties and risks associated with investing in renewable energy, making it far easier to obtain financing.

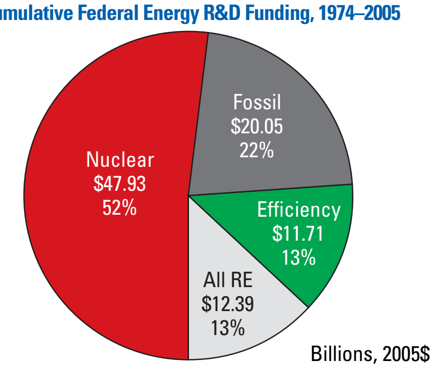
While it is often assumed that feed-in laws are inherently more expensive than quota systems, under the quota system in the United Kingdom, the price paid for wind electricity was similar in 2003 to payments for wind power in Germany. Over time, feed-in prices can be reduced as technologies become more economical.

Furthermore, feed-in laws can help avoid the need for additional subsidies while helping to internalize the social and environmental costs associated with electricity production.

Worldwide, 41 countries, states, and provinces have enacted feed-in laws, and versions of the law have begun to appear in several U.S. states—including Minnesota, New Mexico, Washington, and Wisconsin. Other states are now considering implementing similar laws.

Source: IEA

Cumulative Federal Energy R&D Funding, 1974–2005



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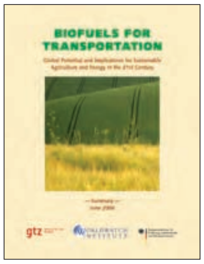

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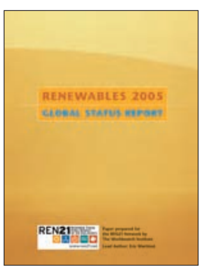

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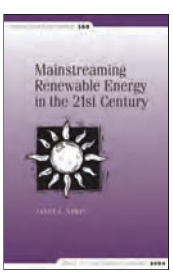

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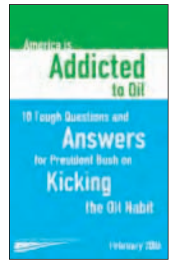

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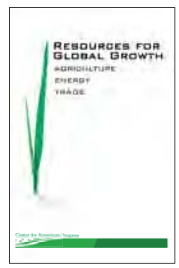

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—Sheikh Yamani, former Oil Minister of Saudi Arabia

"The best way to predict the future is to invent it."

—Alan Kay, pioneer of personal computing

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