THE ROAD TO A NEW ENERGY FUTURE

ENERGY EFFICIENCY AND RENEWABLE ENERGY TECHNOLOGIES FOR A CLEANER, MORE SECURE ENERGY FUTURE

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Energy Efficiency and Renewable Energy Technologies for a Cleaner, More Secure Energy Future

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Table of Contents

Executive Summary

America can and must move away from our dependence on oil and other fossil fuels and toward a New Energy Future. We can do this by tapping into our abundant supplies of clean, renewable, home-grown energy sources and by deploying our technological know-how to use energy more efficiently.

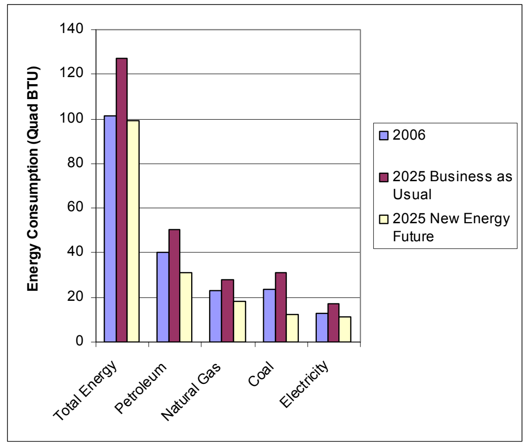
Recognizing the promise of energy efficiency and renewable energy to transform our economy, a group of environmental, consumer, labor and civic organizations have endorsed the New Energy Future platform, which consists of the following four goals:[1]

- **Reduce our dependence on oil** by saving one-third of the oil we use today by 2025 (7 million barrels per day).[2]
- **Harness clean, renewable, homegrown energy sources** like wind, solar and farm-based biofuels for at least a quarter of all energy needs by 2025.[3]
- **Save energy** with high performance homes, buildings and appliances so that by 2025 we use 10 percent less energy than we do today.
- **Invest in a New Energy Future** by committing $30 billion over the next 10 years to the New Energy for America Initiative, thus tripling research and development funding for the energy-saving and renewable energy technologies we need to achieve these goals.[4]

In fall 2006, we released a white paper describing a plausible scenario for achieving those targets and estimating the benefits in terms of fossil fuel savings that would result. According to that analysis, America could achieve major reductions in the use of all fossil fuels by realizing the goals of the New Energy Future platform. By 2025, America could:

- Save **10.8 million barrels of oil** per day, equal to four-fifths the amount of oil we currently import from all other nations in the world.
- Save **9.1 trillion cubic feet of natural gas** per year, nearly twice as much as is currently used annually in all of America's homes and more than is currently used in all of America's industrial facilities.
- Save **900 million tons of coal per year**, or about 80 percent of all the coal we consumed in the United States in 2005.
- Save **1.7 billion megawatt-hours of electricity** per year, 30 percent more than was used in all the households in America in 2005.[5]

Fig. ES-1. Fossil Fuel and Electricity Consumption Under the New Energy Future Scenario[6]



Achieving these fossil fuel savings would help solve many of America's pressing energy problems – ranging from dependence on foreign oil to global warming – and would likely do so while creating jobs and contributing to the long-term stability of America's economy.

This paper describes the technologies – many of which exist today – that can enable America to achieve the goals of the New Energy Future platform.

Energy Efficiency Technologies
Numerous technologies exist to reduce energy use in homes and businesses:

- Home weatherization – including air sealing, insulation and window replacement – can cut energy use for home heating by 20 to 30 percent.
- Efficient furnaces, like those meeting federal Energy Star standards, can cut energy use for heating by 20 percent compared to today's furnaces and by 40 percent compared to those 20 years old or older.
- Solar and heat pump water heaters can reduce energy use for water heating by half to two-thirds, and more water-efficient

clothes washers and dishwashers can provide additional savings.

- Businesses can save energy, too. Wal-Mart, for example, has already committed to reducing its in-store energy use by 20 percent. And one recent analysis found that the use of more efficient motors and improved controls in the industrial, electric and commercial sectors could reduce *total* U.S. electricity demand by as much as 15 to 25 percent.
- New technologies and combinations of technologies – such as those included in zero-energy homes and low-energy commercial buildings – could lead to even more dramatic reductions in fossil fuel use in homes, business and industry in the years to come.

Oil Saving Technologies
America can significantly reduce its consumption of oil by making cars go farther on a gallon of gasoline, reducing the rate of growth of vehicle travel, and using plant-based fuels to substitute for some of the oil we use for transportation.

- Fuel-efficient technologies like advanced engines and transmissions and improved electronics can improve the fuel economy of today's cars by 50 percent or more, while hybrid-electric and other advanced vehicles make a 45 miles per gallon fuel economy standard feasible within the next two decades. Similar improvements can be made to the fuel economy of heavy-duty trucks.
- High gasoline prices are already reducing the growth of vehicle travel in the United States, but expanding the range of transportation choices – through expanded transit and increased support for carpooling, telecommuting, walking and biking – could enable more Americans to avoid high prices at the pump and increasingly frustrating commutes.
- Production of plant-based fuels like ethanol and biodiesel in the United States has more than doubled over the last four years, helping to reduce our dependence on petroleum. New technologies that convert plant residues and energy crops into biofuels could make biofuels a more promising alternative and allow us to further reduce our use of oil in transportation.
- New automotive technologies – like "plug-in" hybrids – are being developed that could bring the dream of 100 MPG cars within reach, or even eliminate the use of oil in vehicles altogether.

Renewable Energy Technologies
America has access to immense renewable energy resources from the sun, earth and crops and from the movement of wind and water. The technology to tap those resources is advancing rapidly and is increasingly competitive in cost with fossil fuel technologies.

- The wind blowing through the Great Plains could generate enough electricity to power the entire country. Wind power installations in the United States have doubled over the last four years, and wind power is among the cheapest sources of new power generation in some parts of the country.
- Solar energy could conceivably generate more than enough electricity to power the entire United States. The cost of solar panels has declined dramatically in recent years and solar power installations worldwide nearly doubled between 2002 and 2004. Continued advances in solar technology could bring solar power within reach of more Americans within the next several years.
- Plant-based sources of energy, called "biomass," already provide a substantial amount of energy in America and can provide even more. A federal advisory group has set a target of having biomass account for 5 percent of industrial and electric generator energy use by 2020.
- Immense amounts of energy are contained within the earth. Experts estimate that as much as 100,000 megawatts of geothermal power – equal to about 10 percent of today's electricity generation capacity – could be economically viable in the United States.

Improving today's clean energy technologies and developing tomorrow's technologies requires a substantial investment in federal energy research and development.

- Federal investment in clean energy research and development (R&D) has resulted in many technological breakthroughs with big dividends for America's economy. A study by the National Academy of Sciences estimated that R&D breakthroughs in just

six energy efficiency technologies yielded economic benefits of about $30 billion on an R&D investment of about $400 million – a return on investment of 75-to-1.
- Federal investment in energy research and development has declined dramatically from its peak during the energy crises of the late 1970s and early 1980s. The United States now spends less than half as much on energy R&D programs in the public and private sectors as it did in 1980. Clean energy programs have faced continued funding pressure in recent Bush administration budget proposals.
- Increasing federal clean energy research and development funding to $3 billion per year – about triple today's funding level – over 10 years would enable researchers to focus on several goals:
  - Improving the performance and economic competitiveness of existing clean energy technologies.
  - Redesigning our energy system to remove existing hurdles to improved energy efficiency and the integration of renewable energy into our economy.
  - Designing new energy efficiency and renewable energy technologies.
  - Reducing the cost of producing clean energy technologies and coordinating "real world" demonstration of those technologies.
  - Addressing any social or environmental impacts of clean energy technologies.

The United States should adopt the goals of the New Energy Future platform and marshal the political, economic and scientific resources necessary to meet those goals.
Public policy changes can play an important role in advancing the nation toward the goals of the New Energy Future platform. The following policies would represent a strong first step:

Energy Efficiency in Homes, Business and Industry
- Set strong energy efficiency standards for household and commercial appliances.
- Strengthen residential and commercial building codes and ensure that they are adequately enforced.
- Require utilities to meet growing energy needs through energy efficiency improvements before building new power plants.
- Expand and invest in energy efficiency programs to help homeowners and businesses install the latest technologies in their homes and businesses.
- Eliminate obstacles to the use of combined heat and power (CHP), which would dramatically improve opportunities for industrial and commercial energy efficiency.

Oil Savings
- Increase fuel economy standards for cars, light trucks and SUVs to 45 miles per gallon over the next decade-and-a-half and set strong fuel economy standards for heavy-duty trucks.
- Set goals for the use of plant-based fuels like ethanol and biodiesel and enact policies that ensure that those fuels are developed cleanly and efficiently.
- Encourage the development and use of advanced technology vehicles like "plug-in" hybrids that can achieve 100 miles per gallon of gasoline or more.
- Invest in expanded and improved public transit service, promote "smart growth" practices that reduce the need for driving, and encourage other transportation choices like telecommuting, carpooling, biking and walking.

Renewable Energy
- Enact a national renewable energy standard, similar to those already in place in 20 states, that would require a minimum percentage of the nation's electricity to come from renewable sources.
- Increase research and development funding to develop the next generation of renewable energy technologies.
- Provide consistent, long-term tax incentives for the installation of renewable energy technologies.
- Require utilities to prioritize renewable energy development over the construction of conventional power plants to satisfy electricity demand.

Introduction

America is the most technologically and economically advanced nation in the world, blessed with vast natural and intellectual resources. Our nation has a track record of responding to major challenges and achieving unthinkable goals. If any nation in the world is capable of creating an energy system that can fuel our economy while preserving our environment and our long-term security, it is us.

But America's energy situation today is less secure than it has been in recent memory. Our domestic production of oil peaked decades ago and our production of natural gas may be peaking now. As a result, we import more of our energy than ever before, leaving our energy supplies and national security vulnerable to political instability abroad. We have ample supplies of coal, but mining it causes severe environmental damage and burning it releases large amounts of global warming pollution. Nuclear power has been tried and found wanting for economic, environmental and public safety reasons. And virtually every year, Americans consume more energy in our cars, homes and businesses.

For America to retain our economic vigor, national security and environmental health, we must build toward a New Energy Future – one based on homegrown, environmentally friendly energy sources and the sensible use of energy throughout the economy.

We have the tools to achieve a better energy future – in the technological prowess of academia and industry, the cutting-edge public policies now being pioneered in states across the country, and in our vast reserves of energy from the sun, wind and crops.

THE NEW ENERGY FUTURE PLATFORM

In order to achieve a New Energy Future, we need to set ambitious goals for how we will transform our economy to reduce our dependence on fossil fuels, and then marshal the political, economic and technological resources to achieve those goals.

In 2006, a broad coalition of environmental, consumer, labor and civic groups gave their endorsement to a New Energy Future platform that includes the following goals: [7]

- **Reduce our dependence on oil** by saving one-third of the oil we use today by 2025 (7 million barrels per day).[8]
- **Harness clean, renewable, homegrown energy sources** like wind, solar and farm-based biofuels for at least a quarter of all energy needs by 2025.[9]
- **Save energy** with high performance homes, buildings and appliances so that by 2025 we use 10 percent less energy than we do today.
- **Invest in a New Energy Future** by committing $30 billion over the next 10 years to the New Energy for America Initiative, thus tripling research and development funding for the energy-saving and renewable energy technologies we need to achieve these goals.[10]

In fall 2006, we issued a white paper entitled *A New Energy Future: The Benefits of Energy Efficiency and Renewable Energy for Cutting America's Use of Fossil Fuels*. The paper found that, under one plausible technological pathway for meeting the goals of the New Energy Future platform, the United States could, by 2025:

- Save **10.8 million barrels of oil** per day, equal to four-fifths the amount of oil we currently import from all other nations in the world.
- Save **9.1 trillion cubic feet of natural gas** per year, nearly twice as much as is currently used annually in all of America's homes.
- Save **900 million tons of coal per year**, or about 80 percent of all the coal we consumed in the United States in 2005.
- Save **1.7 billion megawatt-hours of electricity** per year, 30 percent more than was used in all the households in America in 2005.[11]

Such reductions in fossil fuel consumption would address many of the energy-related challenges facing the United States today, including our exposure to high and volatile prices for fuels like oil and natural gas, our dependence on foreign nations for crucial energy supplies, and our emissions of pollutants that cause global warming, which threatens to have dramatic impacts on America's environment, economy and public health.

ABOUT THIS PAPER

This paper is a companion to the September 2006 white paper. In this paper, we describe many of the technologies that can help America to achieve the New Energy Future goals.

A review of these technologies leads to the conclusion that America *already has* most of the tools we need to achieve the targets of the New Energy Future platform. Energy efficiency technologies exist that can dramatically reduce the amount of energy we use in our homes, businesses, industries and vehicles. And renewable energy technologies like wind turbines, solar panels and plant-based fuels like ethanol are experiencing spectacular rates of growth, both in the United States and worldwide.

The next steps are to develop and implement public policies that can put these clean energy tools in the hands of individuals and businesses, and to continue to push forward on research and development of a new generation of clean energy technologies.

The potential for America to achieve a New Energy Future is real. The need to do so is great. And the time we have to make the transition is short. The clean energy technologies highlighted in this paper – combined with new technologies that we can develop through a focused, sustained, well-supported research and development effort – give us an opportunity to break, once and for all, America's dependence on fossil fuels and put our nation on a more secure energy footing for generations to come.

It is time to take advantage of that opportunity.

Energy Efficiency Technologies

Improving the energy efficiency of America's economy is the cheapest and quickest way to reduce our dependence on fossil fuels. Vast "strategic reserves" of energy efficiency exist within America's homes, businesses and industrial facilities – reserves that we can largely tap using technologies available today.

Energy Efficient Homes

From top to bottom, America's homes hold great potential for improvements in energy efficiency.

SPACE HEATING

Space heating is the largest source of energy consumption in homes, accounting for nearly half of residential energy use.[12] Despite dramatic improvements to the energy efficiency of the average American home since the energy crises of the 1970s, large opportunities remain to reduce energy consumption for space heating.

There are multiple ways to reduce energy consumption for space heating in American households. Improved insulation, high-efficiency windows and weather-stripping can reduce the amount of heat that escapes from a home during cold weather. And high-efficiency furnaces and boilers can ensure that less fossil fuel is wasted in the production of heat for homes.

Home weatherization measures, like proper insulation, can shave home heating fuel use by as much as 30 percent.
Credit: DOE/NREL, Karen Doherty

Most American homes – both new and existing – can be heated far more efficiently. For three decades, for instance, the federal government has been providing grants to state agencies that help low-income households improve their energy efficiency through the Weatherization Assistance Program. A recent evaluation of the program in 19 states found that the program reduced natural gas consumption for space heating in affected homes by approximately 32 percent. In addition, the program provided societal benefits about 2.5 times as great as the program's cost.[13]

A variety of technologies can make existing homes more energy efficient:

- Air sealing, insulation and window replacements can reduce energy consumption by 20 percent.[14]
- High-efficiency residential furnaces, such as those meeting the federal government's Energy Star standards, can reduce fuel use by about 20 percent compared to furnaces meeting the government's minimum furnace efficiency standard, and by 40 percent or more compared to older furnaces.[15] Considering that about one-quarter of all homes have furnaces that are 20 years old or older, the opportunity for energy savings is large.[16] The federal government recently missed an opportunity to strengthen energy efficiency standards for natural gas furnaces, despite the availability of technologies that can provide a significant boost to furnace efficiency.[17]

Similar opportunities exist for new homes. Many new homes across the country are not built to modern energy efficiency standards. For example, 16 states currently have building energy codes that date to 1998 or prior, despite significant increases in the strength of building energy codes since then.[18] Moreover, enforcement of building energy codes is often lax; a 2001 study estimated that less than half of new homes in one state fully complied with the state's building energy code.[19] Simply adopting the most recent and most stringent building energy codes and improving enforcement could lead to dramatic savings of energy in new homes. The Alliance to Save Energy, for example, estimates that building energy codes for residential and commercial buildings could save 0.85 quadrillion BTU (quads) of energy annually by 2020 – or about 2 percent of the total energy consumed in homes and businesses in 2005.[20]

But requiring new residential construction to meet current energy codes is just the tip of the iceberg for the energy savings that can be achieved in new homes. New homes meeting federal Energy Star energy efficiency standards provide energy savings of at least 15 percent compared with the most recent (and most stringent) residential model building code.[21] And builders in parts of the country are now constructing "zero-energy homes" in which fossil fuel purchases are virtually zero. (See "The Next Wave: Zero-Energy Homes" below.)

AIR CONDITIONING

Air conditioning accounts for 16 percent of residential electricity consumption.[22] New federal standards for residential and commercial air conditioners will improve efficiency for new units by 30 percent and 26 percent, respectively.[23] However, air conditioners currently exist that exceed the new federal standard by 15 percent or more. Moreover, simple changes in building design and appropriate weatherization can reduce the need for air conditioning. For example, light colored "cool roofs" that reflect rather than absorb the sun's heat have been shown to reduce cooling energy use by approximately 40 percent.[24]

WATER HEATING

Water heating accounts for about 17 percent of household energy use.[25] As with other sources of household energy demand, significant energy savings are possible from switching from less energy efficient to more energy efficient equipment. In addition, some technologies that save water – such as front-loading clothes washers – can also reduce demand for hot water and reduce fossil fuel use.

Even greater savings are possible by using technologies that tap renewable energy sources to assist in water heating. Heat pump water heaters, for example, use less than half as much electricity as traditional electric water heaters.[26] And solar water heaters, which use roof-mounted solar collectors to heat household water, can reduce energy consumption for water heating by about two-thirds and pay for themselves within four to eight years.[27]

APPLIANCES

American homes are full of energy-consuming appliances – the vast majority of which can be made dramatically more energy efficient.

If every American installed compact fluorescent light bulbs like these, we could cut our total household lighting bill in half.
Credit: DOE/NREL, D&R Int. LTD

The biggest energy-consuming appliance in most American homes is the refrigerator, which consumes 14 percent of residential electricity.[28] Federal efficiency standards for refrigerators have resulted in vast improvements in energy efficiency; the average refrigerator sold today uses one-third the electricity as the average unit from 1974, despite an increase in average size and performance.[29] Still, significant energy savings are possible by replacing older refrigerators with newer models. Refrigerators meeting Energy Star efficiency standards, for example, are 10 to 15 percent more efficient than average models.[30]

Similar gains are possible with other appliances – including appliances that are on the cutting edge of technology, like DVD players and other digital media. For example, many electrical appliances, including televisions, cable set-top boxes and stereos consume power even when they are turned off. One study of 10 California homes found that consumption of standby or "vampire" power accounted for between 5 and 26 percent of the homes' annual electricity use.[31] Replacing existing appliances with those that minimize standby power use could reduce these losses by 68 percent.[32]

LIGHTING

Compact fluorescent light bulbs are becoming increasingly common in American homes and are vastly more efficient than traditional incandescent bulbs. Lighting accounts for about 9 percent of household electricity consumption.[33] If every American household replaced its most highly used incandescent bulbs with compact fluorescents, America's total household lighting consumption could be cut in half.[34]

PUTTING IT ALL TOGETHER

As shown above, there are many opportunities to reduce energy consumption in American homes. Aggressive weatherization of homes, combined with installation of high-efficiency furnaces, could reduce energy consumption for space heating by 20 to 40 percent or more. Similar energy savings are available for energy used in water heating, lighting, air conditioning, and many appliances.

Could all of these improvements, put together, lead to a 10 percent reduction in home energy use within the next two decades? The experience of California suggests they can.

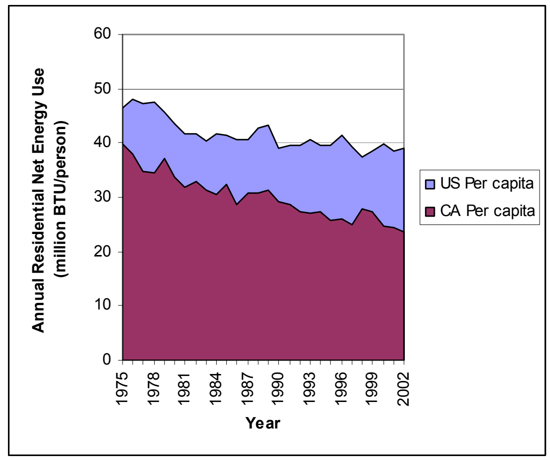
California has long been a leader in energy efficiency. It was the first state to adopt energy efficiency standards for home appliances, has the nation's most stringent building energy codes, and has long had well-funded, aggressive programs for promoting energy efficiency. While homes have become more efficient across the U.S., California has truly excelled. On a per-capita basis, the U.S. used 16 percent less energy in homes in 2002 than it did in 1975. But in California, residential energy use declined by more than 40 percent per capita between the mid-1970s and 2002.[35] (See Fig. 1.)

If the United States had achieved the same per-capita percentage reduction in residential energy

This Colorado home looks typical, but it holds a secret – it is a zero net energy home built by the Department of Energy for Habitat for Humanity. The home uses solar panels and a solar hot water system to produce as much energy as it consumes.
Credit: DOE/NREL, Paul Norton

use between 1975 and 2002 as California did, the nation would have consumed over 3 quadrillion BTU less energy in 2002. Moreover, residential energy consumption in the U.S. would have been 17 percent *lower* in absolute terms than it was in 1975, rather than 12 percent higher.[36]

Fig. 1. Per-Capita Residential Energy Consumption, U.S. versus California



The California experience, coupled with the availability of a wide variety of energy efficiency technologies for American homes, suggests that the goal of reducing home energy use by 10 percent within the next two decades is reachable, if we adopt an aggressive set of public policies that ensure that energy efficient technologies find their way into more American homes. This level of savings could happen using technologies that exist today – not including the likely development of new energy efficient technologies that could transform the way American homes use energy.

THE NEXT WAVE: ZERO-ENERGY HOMES

"Zero-energy" homes are those that are able to produce about as much energy as they use. Zero-energy homes typically combine an array of energy-saving technologies with small-scale renewable energy production. For example, the U.S. Department of Energy worked with Habitat for Humanity to design and build several near-zero-energy homes in Tennessee. The buildings combine an airtight building envelope with energy-efficient windows, a geothermal heat pump, solar panels and energy-efficient appliances. Costs for building the homes were around $100,000 and daily expenditures for purchased energy were about $1 per day.[37] A similar model home was built in Colorado. Near-zero-energy homes are becoming increasingly common in California and have the potential to dramatically reduce all forms of residential energy consumption.

Energy Efficiency in Business and Industry

Just as there is tremendous potential for improvements in the energy efficiency of American homes, so too is there great potential for energy savings in business and industry.

Commercial buildings like shopping centers, big box stores, office buildings and institutional buildings (like schools and hospitals) are major consumers of energy, accounting for about 18 percent of total energy use in the United States.[38] Many of the same strategies that are available for reducing residential energy use also apply – on a much larger scale – to commercial buildings. For example, comprehensive energy efficient retrofits for commercial buildings can achieve energy savings on the order of 11 to 26 percent.[39] To give some idea of the potential, Wal-Mart, the nation's largest private electricity user, recently pledged to reduce energy consumption at its stores by 20 percent and has committed to developing a prototype store that curbs energy consumption by 25 to 30 percent.[40]

Lighting and air conditioning equipment used in commercial buildings can be made far more energy efficient. State-of-the-art lighting systems in commercial establishments have the potential to reduce energy consumption for lighting by up to 40 percent nationally.[41] As mentioned above, new federal standards for air conditioners will lead to dramatic improvements in energy efficiency, and air conditioners are already on the market that surpass those energy efficiency standards.

In addition, there are many opportunities for commercial facilities to use energy more intelligently. Variable-speed motors, automated lighting and climate controls, and even the simple act of turning off lights at the end of the workday can save large amounts of energy. For example, Adobe Corporation implemented a series of energy efficiency measures at its San Jose, California headquarters – including installation of variable-speed motors and high-efficiency lighting systems, and adjusting lighting and climate controls to the actual needs of the building. Over the past six years, as a result of the measures, Adobe has reduced per-employee electricity use at its headquarters by 35 percent and natural gas use by 41 percent.[42]

Combined heat-and-power (CHP) technologies represent yet another opportunity for energy savings in both commercial buildings and industrial facilities. Many large apartment buildings, commercial developments and industrial facilities could make greater use of CHP, in which heat produced to warm buildings or power industrial processes is also used to generate electricity. CHP systems can reach 70 to 90 percent thermal efficiency, compared to the 33 percent efficiency of today's power plants.[43]

Software maker Adobe launched an aggressive effort to improve the energy efficiency of its San Jose headquarters, cutting per-employee electricity use by 35 percent. Credit: Proehl Studios® April 2006

Many industrial facilities already use CHP, but the potential for growth is enormous. Studies conducted for the U.S. Department of Energy found a market potential of 33,000 megawatts for industrial CHP systems (compared to current deployment of 11,000 megawatts), and as much as 77,000 megawatts in the commercial and institutional sector (compared to deployment of 5,000 megawatts as of 1999).[44] Building out this existing CHP potential would equal about 10 percent of America's current electric generation capacity, and technological improvements could allow CHP technologies to spread even farther in the years to come.[45]

Industrial facilities can also achieve much greater energy efficiency. In addition to increasing the use of combined heat and power, other measures that could save large amounts of energy include the following:

- **Advanced Motors** – The use of high-efficiency motors and better controls in the industrial, electricity generation and commercial sectors could reduce *total* U.S. electricity demand by as much as 15 to 25 percent.[46]

- **Efficient Boilers** – Industrial boilers produce steam and hot water for manufacturing processes. Significant improvements in efficiency – on the order of 15 to 19 percent – are possible for oil and natural gas boilers.[47]

- **Recycling** – Much of the oil used by industry is not consumed for energy purposes, but as feedstocks for products like plastics and asphalt. Consumption of petroleum for feedstocks can be reduced by more aggressive recycling to replace the use of virgin materials in these products. The Rocky Mountain Institute, for example, estimates that, if the United States increased its rate of plastics recycling to that of Germany, the use of petroleum feedstocks used in manufacturing could be cut by 12 percent.[48]

- **Thermal Efficiency** – Factories can achieve dramatic improvements in efficiency through techniques that seek to maximize the efficiency of the industrial process as a whole, rather than just the component parts. Using a technique called "pinch analysis," engineers can estimate the minimum amount of energy theoretically required at a given facility and make adjustments to processes in order to maximize energy efficiency. Such analyses can reduce energy costs by as much as 40 percent.[49]

PUTTING IT ALL TOGETHER

Just as is the case with residential buildings, there are a wide variety of technologies available to reduce energy use in businesses and industry. But in some key ways, commercial and industrial buildings may hold greater opportunities for efficiency improvements through the application of professional management and analytical techniques to reduce energy waste that may be hurting a company's bottom line. Many businesses have saved large amounts of energy by undertaking a thorough analysis of how energy is used in their facilities and applying appropriate technologies and practices to minimize energy consumption.

The potential for cutting-edge technology and smart thinking to dramatically reduce energy consumption in buildings and industry is epitomized by the current drive in the American architecture community to encourage "green building" techniques.

THE NEXT WAVE: GREEN BUILDINGS

Interest in "green buildings" has mushroomed in recent years among companies and government agencies seeking to improve their environmental performance. Green building certification programs such as Leadership in Energy and Environmental Design (LEED) have come to be seen as an important symbol of an organization's environmental commitment. The number of LEED-certified buildings nationwide approximately doubled in 2005.[50]

Now, a group of architects is working to ensure that all new commercial buildings meet exacting energy efficiency criteria. The American Institute of Architects has set a goal of reducing fossil fuel use in the construction and operation of new buildings by 50 percent by 2010, with additional 10 percent reductions in fossil fuel use every five years beyond then.[51] Similar transformative potential may also be possible in industry by reconsidering product design, product flows and industrial facility design in order to reduce the use of feedstocks and minimize energy waste.

Oil Saving Technologies

The United States is by far the largest consumer of oil in the world, consuming more than 20 million barrels a day. America could reduce its consumption of oil by half that amount over the next 20 years using a range of strategies and technologies to use oil more efficiently and to find renewable products to do the jobs in our economy that oil does today.

Nearly two thirds of the oil we use each year powers cars, trucks, airplanes and other forms of transportation. Another quarter is used in industry, with oil use in the residential, commercial and electricity sectors accounting for about 9 percent.[52] There are various ways to curb oil consumption in each of these areas of America's economy.

Transportation

There are three ways to cut oil consumption from transportation – make vehicles go farther on a gallon of fuel, reduce the rapid rate of growth in the number of miles Americans drive, and use renewable fuels to replace some of the oil we currently use for transportation.

FUEL ECONOMY

Between 1975 and 1988, the fuel economy of new passenger cars in America nearly doubled —from 13.4 miles per gallon (MPG) in 1975 to 24.4 MPG in 1988.[53] Similarly, light trucks experienced an increase in real-world fuel economy from 11.6 MPG in 1975 to 18.4 MPG in 1987.[54] The reason: the imposition of federal Corporate Average Fuel Economy (CAFE) standards in the wake of the 1973 oil crisis.

By the late 1980s, CAFE standards were saving America millions of barrels of oil per year. But since the late 1980s, automakers and the federal government have taken their eye off the ball, allowing CAFE standards to stagnate and flooding the market with large, low-mileage SUVs. As a consequence, the average new light-duty vehicle sold in 2005 had *worse* fuel economy than the average vehicle sold in 1982, despite rapid advances in automotive technology over that time period.[55] The failure to maintain momentum toward more fuel-efficient cars represents a tremendous missed opportunity for energy savings that has left us more vulnerable to volatile oil prices and disruption of key oil supplies from abroad.

Over the last several years, many analysts – ranging from environmental advocates to the National Academy of Sciences – have identified dozens of technologies that exist today or will be available soon that can significantly boost the fuel economy of vehicles.

Among them:

- **Efficient engines**, using technologies like variable valve timing, cylinder deactivation (in which engine cylinders are shut off when not needed, such as at highway cruising speeds), turbocharging, and the use of improved lubricants.
- **Efficient transmissions**, including 5- and 6-speed automatic transmissions and continuously variable transmissions.
- **Improved aerodynamics and reduced rolling resistance** to reduce the amount of energy lost to friction with the air and the road.
- **Enhanced electronics**, such as 42-volt electrical systems and integrated starter generators that allow the engine to be shut off when the vehicle is stopped.[56]

None of these technologies are new or exotic. Indeed, many have been installed in limited numbers in passenger cars sold by major manufacturers, and the potential they hold for fuel economy gains is significant. An analysis by the Union of Concerned Scientists based on a 2002 National Academy of Sciences (NAS) study found that the technologies evaluated by the NAS could raise average vehicle fuel economy to 37 miles per gallon (from 24 miles per gallon today) at a net financial benefit to consumers, and do it by 2017.[57]

Indeed, it is likely that we can go much farther. The NAS report did not include the hybrid-electric vehicle technology that has become increasingly common on America's roads, nor did it include lightweight, high-strength materials that can safeguard passenger safety while reducing vehicle weight and improving fuel economy.[58] Hybrid technology, in particular, holds great promise for driving future gains in fuel economy. The best hybrids – like the Toyota Prius, Toyota Camry hybrid, Honda Civic hybrid and Ford Escape hybrid – can increase fuel economy by 40 to 80 percent.[59] And more American consumers are demanding them –

sales of hybrid vehicles have increased dramatically each year since they were introduced to the United States in 2000. Hybrid vehicle sales in 2006 are on track to surpass last year's record of 205,000 vehicles and more hybrid models are coming soon.[60]

By fully adopting the fuel economy technologies available today and encouraging greater deployment of hybrid vehicles, the United States could achieve an average fuel economy standard of 45 MPG within the next decade and a half.[61] As we will discuss below, such an improvement represents only a fraction of what could be achieved by advanced new technologies now being researched by automakers and others.

Similar improvements are possible for the fuel economy of the heavy-duty trucks that carry freight on America's highways. Unlike cars and SUVs, tractor-trailers are not currently subject to any federal fuel economy standards. But like those vehicles, the fuel economy of tractor-trailers has been on the decline for the last decade.[62]

Manufacturers have the technology to make tractor-trailers far more efficient than they are today, using tools like advanced electronics, better aerodynamics and transmission and engine improvements. The American Council for an Energy-Efficient Economy estimates that heavy-duty trucks could be made to be 58 percent more energy efficient than today's models – and that the investment in more efficient vehicles would be more than paid for by the savings in fuel costs over time.[63]

VEHICLE TRAVEL AND TRANSPORTATION SYSTEM EFFICIENCY

Improving the fuel economy of our cars, trucks and other forms of transportation is an important step for reducing oil consumption. But if we are going to reduce our dependence on foreign oil, we also need to reduce the dramatic rate of growth in vehicle travel. There are many ways to achieve that goal and to enhance the overall efficiency of our transportation system.

Americans are driving more miles in our cars and SUVs than ever before. In 1980, for example, the average American driver drove a car or light truck about 6,200 miles per year. By 2004, the average American was driving nearly 50 percent more miles per year.[64] And, if we continue on our current, business-as-usual path, the average American will be driving 2,000 more miles per year in 2025 than he or she does today.[65] To save large amounts of oil versus business as usual projections, Americans simply need to not drive more than we do today (acknowledging that vehicle travel will continue to increase somewhat due to population growth).

Many Americans are already looking for alternatives to daily commutes that have grown increasingly expensive due to high gas prices and increasingly frustrating due to mounting congestion. Indeed, higher gasoline prices have already led many Americans to cut down on driving when they can and to use alternatives where they are available. In 2005, the number of vehicle-miles traveled nationwide increased by approximately 0.1 percent, the slowest rate of increase since 1980.[66] And, from January through July 2006, the number of vehicle-miles traveled had also increased by a scant 0.1 percent over a similar period in 2005.[67]

But those reductions in the growth of vehicle travel have come in the face of huge increases in gasoline prices, demonstrating that, for many Americans, alternatives to driving are few. Expanding the range of transportation choices available to Americans means retooling our communities to provide options other than using a car and investing in efforts to promote transit, telecommuting, carpooling, biking, walking and other alternatives.

Achieving reductions in the growth of vehicle travel is certainly possible. Indeed, there are many American metropolitan areas whose residents drive significantly less than the national average. Based on 2003 data from the Texas

Expanded and improved public transportation can provide Americans with alternatives to increasingly costly and frustrating commutes. Credit: Massachusetts Bay Transportation Authority.

Transportation Institute, vehicles traveled less than 7,500 miles per year on average in the Chicago, Sacramento, Philadelphia, Buffalo and New York metropolitan areas for every resident of those areas. By contrast, more than 12,000 miles were traveled per resident in the Orlando, Atlanta and Birmingham, Alabama metro areas.[68]

There are many reasons why residents of one metropolitan area may drive less than residents of another, but two factors that are almost certainly at play are the availability of efficient, high-quality transit service and the existence of development patterns that enable residents to take advantage of transit and other transportation alternatives. For example, in the Birmingham, Alabama metropolitan area in 2003, 479 miles were traveled in cars for every passenger-mile traveled via transit. In New Orleans, that ratio was 37-to-1; in Portland it was 26-to-1; and in New York it was 6-to-1.[69]

But transit doesn't just work in older, concentrated central cities like New York. It is also proving to be an effective transportation choice in cities that aren't normally seen as havens for transit – places like Dallas, Denver and Salt Lake City. Each of these cities has built or added to light rail transit networks over the past decade and a half, experiencing surprisingly high passenger counts.[70] And as prices at the pump have increased, riders have flocked to transit in cities across the country. Ridership on Los Angeles' light rail transit lines increased by 12 percent in the first half of 2006 alone. Ridership also increased by 6 percent in Dallas, 6 percent in St. Louis, 3 percent in Portland and 2 percent in Denver.[71] In addition, a variety of cities – most notably Portland, Oregon – have paired expansion of transit service with "transit-oriented development" that orients new residential and commercial development around transit stops.

One major roadblock to building a 21st century transit system capable of providing Americans with more transportation choices has been the lack of adequate and reliable funding. In 2004, for example, all levels of government – federal, state and local – invested a combined $150 billion taxpayer dollars on highway improvement, maintenance and operation.[72] By contrast, investment in transit by all levels of government in 2004 amounted to only $26 billion.[73]

But while a major investment in transit and improved land-use policies and practices will be needed to provide Americans with more transportation choices, there is also much that can be done with little expenditure of money. Government and employers can help Americans maximize their transportation choices by encouraging carpooling, telecommuting, walking and biking, among other alternatives.

High gasoline prices have already caused the growth in vehicle travel to slow nearly to a halt in 2005 and so far in 2006. Preventing future growth in vehicle travel over the long term, however, will require a conscious, well-funded effort to create more transportation choices for Americans hungry for alternatives to higher gas prices and frustrating commutes, as well as sensible changes in how we organize our communities. With such efforts, it is reasonable to assume that the United States could hold the growth in vehicle travel to the rate of population growth over the next two decades.

Transit-oriented developments, like this one in Portland, Oregon, are designed to make it easier for residents to walk, bike and use transit to complete their daily activities.

Reducing growth in car and light truck travel is just one way America can make its transportation system more efficient. Moving freight by rail, for example, takes only one-tenth of the energy of moving freight by truck, yet some sections of the country have freight rail networks that have inadequate capacity or are outmoded.[74] Similarly, public investment in airports has helped fuel a large increase in air travel nationwide over the past couple of decades. Yet, America's passenger rail network – which has the potential to carry intercity passengers more efficiently than air travel (and, with high-speed rail, about as quickly in some travel corridors) – has been allowed to atrophy. Creating a balanced transportation system will also require investments in rail as well as in improvements in connections to allow the seamless transfer of people and freight among various travel modes.

PLANT-BASED FUELS

The final aspect of cutting oil consumption is to find other fuels and materials to do the jobs in our economy that oil does today. One way to do so is to use plant-based fuels like ethanol and biodiesel to replace some of the oil we currently use in cars and trucks. Plant-based fuels and products will likely never replace petroleum entirely – at least not unless we cut our petroleum use way back from current levels. But they can be part of the solution, particularly if they are produced in ways that use as little fossil energy as possible and are protective of the environment.

Not all "biofuels" are alike. Today, most of our ethanol comes from corn, which is fairly energy-intensive to grow and process into biofuels. (Although even corn ethanol uses less oil to produce than it provides in useful fuel, according to most studies.)[75] Many experts believe that we will reap the greatest energy-saving potential from biofuels from specially grown "energy crops" like switchgrass and from plant residues. At the moment, however, the technology for processing energy crops and plant residues into biofuels is in the early stages of development.

There is reason to believe that biofuels can come to play a significant role in replacing a significant share of transportation fuels in the foreseeable future:

- The domestic ethanol industry has grown dramatically in the last half decade, producing more than twice as much ethanol in 2005 as was produced in 2001.[76] And that growth is expected to continue – plans for new and expanded plants will increase the nation's ethanol production capacity by 60 percent.[77]

- While most of today's ethanol is being produced from corn, scientists continue to make progress toward development of cellulosic ethanol from plant residues and energy crops. Recently, Honda and a research institute in Japan announced what they term a breakthrough in the production of cellulosic ethanol, along with plans to build a "biorefinery" based on the process that will produce both ethanol and other products.[78] A group of academics and non-profit experts projects that the United States could produce as much as 13 billion gallons of cellulosic ethanol per year by 2025.[79]

- Significant potential exists for plant-based biodiesel as well. U.S. production of biodiesel tripled between 2004 and 2005 to 75 million gallons.[80] And the U.S. Department of Energy estimates that America could produce 10 billion gallons of biodiesel each year by 2030.[81]

America will need to exert caution in expanding its production and use of plant-based fuels like ethanol and biodiesel. If produced inefficiently or without care for the environment, plant-based fuels can provide few environmental or energy benefits, and the harm could exceed any benefits. But plant-based fuels have great potential to reduce oil consumption for transportation and are an important part of an overall strategy to curb America's dependence on fossil fuels.

Other Uses of Petroleum

Transportation consumes most of the petroleum America uses each year, but other sectors of the economy – particularly industry – consume significant amounts of oil as well. As noted earlier, most petroleum consumed in industry is used to make products, not power machinery. In addition to savings available through energy efficiency and recycling, the potential exists to use plant-based products to replace some of the oil used in industry.

Plant-based fuels like ethanol and biodiesel could someday replace a significant share of the oil we use for transportation. Credit: Charles Bensinger

Plant-based materials can be used as substitutes for petroleum-based materials in the manufacture of chemicals, plastics and other products. Cellulose or starch from wood, cotton, corn or other crops can be converted into biodegradable polymers that can be used as substitutes for plastics in a variety of products.[82] Similarly, plant sugars can be used to create a variety of chemicals.[83] One of the most interesting proposals for the use of biomass is the design and creation of "biorefineries" in which plant-based materials are distilled into a variety of products, including fuel and product feedstocks, at one integrated facility.[84] The Biomass Research & Development Technical Advisory Committee, which advises the U.S. government on biomass issues, has set a target of obtaining 18 percent of America's chemicals from biobased materials by 2020 and 25 percent by 2030.[85]

PUTTING IT ALL TOGETHER

Slashing our consumption of oil is challenging, but it is doable. Indeed, America has already done it once before.

In 1977, the United States consumed 18.8 million barrels of oil per day – then an all-time high. By 1983, America had reduced its oil consumption to 15.2 million barrels per day, a reduction of nearly 20 percent in just six years.[86] Not until 1998 would America consume as much oil as it did in 1977.

Many of the tools used to achieve those savings are available to us today – higher fuel economy standards and improvements in energy efficiency among them. But new, advanced technologies in vehicles and plant-based fuels give us opportunities to reduce oil consumption in ways that didn't exist in the late 1970s and early 1980s. By combining those tools, America can save more than one-third of the oil it consumes today by 2025 – dramatically reducing our dependence on foreign nations for petroleum supplies.[87]

THE NEXT WAVE: ADVANCED VEHICLES

New vehicle technologies – including "plug-in" hybrids and hydrogen fuel-cell vehicles – have the potential to further transform the way we fuel our cars and trucks.

Plug-in hybrids are like conventional hybrids such as the Toyota Prius, but with one key difference: they contain larger batteries that are partially charged with electricity from the power grid. A recent study found that a plug-in hybrid capable of traveling on electricity alone for 20 miles could reduce gasoline consumption by 30 percent compared to today's hybrids. A plug-in with 60 miles of all-electric range could reduce gasoline consumption by two-thirds – bringing the 100 mile-per-gallon car within sight.[88] No automakers are currently making plug-in hybrids, but several are investigating the technology. And while battery technology will need to improve, and price to come down, before plug-in hybrids gain wide acceptance, the technology holds great potential to reduce petroleum use in transportation.

Hydrogen fuel-cell vehicles use hydrogen as part of an electrochemical reaction that produces electricity that can be used to power a vehicle. Hydrogen can be produced in a variety of ways, including through the use of renewable energy. Technology for hydrogen fuel-cell vehicles has been slow in developing – and fuel cell vehicles may not come to wide-scale commercialization for another decade or two – but several major automakers are committed to the technology and have placed demonstration vehicles in service. Honda, for example, has committed to begin limited marketing of its FCX fuel cell vehicle in Japan and the United States in 2008, while General Motors is planning to place 100 fuel-cell SUVs with customers in the fall of 2007.[89]

Plug-in hybrids and fuel-cell vehicles require energy to produce electricity or hydrogen fuel. Fully maximizing the benefits of plug-in hybrids

The socket on the bumper of this plug-in hybrid electric vehicle allows the user to recharge the vehicle's battery using power from the electric grid, reducing the need for gasoline. Credit: DOE/NREL, Keith Wipke.

and fuel-cell vehicles will require generating as much of that energy as possible from renewable energy sources. Using electricity from coal-fired power plants to fuel plug-in hybrids, for example, would generate far fewer benefits in terms of fossil fuel consumption or pollutant emissions than generating that electricity from clean renewable sources.

In addition, it is possible to combine several technologies to achieve even greater reductions in fossil fuel use. For example, one could use plant-based fuels in a plug-in hybrid to reduce petroleum use in cars to a bare minimum. Using such vehicles in an improved transportation system that minimizes the need to drive could result in dramatically reduced oil consumption in vehicles.

Plug-in hybrids, fuel-cell vehicles and other advanced vehicles may not be able to make a sizable contribution next year or before the end of this decade. But they are potentially "disruptive" technologies that can reduce, or even break, America's dependence on oil for transportation.

Renewable Energy Technologies

America has virtually unlimited potential for the generation of power from the wind, sun and other natural forces. Recent advances in technology make renewable energy an increasingly affordable and attractive resource for providing America's energy needs.

Using renewable energy to satisfy one-quarter of America's energy needs by 2025 is an aggressive "reach goal" that will require the United States to identify and marshal resources to tap into the nation's vast potential for energy from natural forces. Many renewable resources can help us get there.

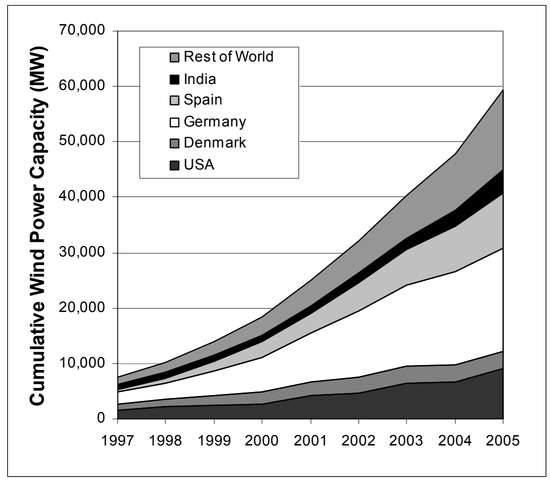
Wind Energy

The wind that blows through America's Great Plains could theoretically generate enough electricity to power the entire country.[90] America's offshore areas could support wind turbines nearly equal in capacity to all the power plants operating in the country today.[91] And other parts of the country, particularly the Northeast, the Appalachian and Rocky Mountains, and the Pacific coast also have access to strong, consistent winds.

The cost of wind turbines has declined by approximately 90 percent over the past two decades and the technology itself has improved to the point where wind power is now cost-competitive with fossil fuel electricity generation in certain parts of the country.[92] The result has been a boom in wind power development – both in the United States and around the world. Wind power installations in the United States just passed the 10,000 megawatt mark, representing a doubling in U.S. wind power capacity in just four years.[93] But other nations have been adding wind power capacity at a faster clip than America. At the end of 2005, Germany had twice the amount of installed wind capacity as the United States, while Spain doubled its wind power capacity within just three years.[94] Worldwide, there is now nearly 60,000 megawatts of wind power capacity, with two-thirds of it in Europe.[95] (See Fig. 2.)

Wind power is becoming an increasingly cost-effective means of generating electricity across the United States. Credit: DOE/NREL, Tennessee Valley Authority.

Fig. 2. Cumulative Installed Wind Power Generating Capacity[96]



More wind power projects are in the pipeline. An additional 6,000 megawatts of wind power projects were in the planning process across the country as of August 2006, according to the American Wind Energy Association, although not all of these proposed projects will end up being built.[97]

But America's current wind energy capacity merely scratches the surface on wind's ultimate potential. A recent study conducted for the U.S. Department of Energy found that, with strong and consistent public policy support, the United States could build as much as 480,000 megawatts of wind energy capacity by 2025, equal to about half of America's current electric generating capacity.[98] And that's not counting the vast wind resource off America's shores.

An electricity system that generates large amounts of power from the wind will require some changes from our current fossil fuel-based system. Investments in transmission lines will need to be focused on bringing wind power from where it is available to where it is needed. The electric grid will need to balance wind power with other forms of generation so as to account for the intermittency of wind resources. And of course, wind power projects will need to be sited and operated in ways that have minimal impacts on the environment and wildlife. But the experiences of nations like Denmark, Germany and Spain – which obtain significant shares of their overall electricity generation from wind power – demonstrate that it is possible to shift 20 percent or more of the nation's power generation to wind without adverse affects on the reliability of the electricity system.[99]

Solar Power

Like the energy of the wind, the energy contained in sunlight striking the United States is more than sufficient to provide for all of America's electricity needs. The potential for electricity from solar in the United States is huge; covering a square of Nevada desert 100 miles on a side with solar panels could produce enough electricity for the entire United States.[100] Of course, no one is proposing that we cover much of Nevada with solar panels – part of the beauty of solar power is that it can be installed on rooftops, garages and other locations, and there are many parts of the United States with adequate sunlight to support solar power.

As with wind power, the price of solar panels and collectors has declined dramatically – with the price of a photovoltaic (PV) system declining at an average rate of about 4 percent per year over the last 15 years.[101] Solar power remains more expensive than other sources of energy and prices have increased slightly in the past year due to a shortage of high-grade silicon. But the solar power industry believes that with enhanced economies of scale and technological advances, the price of solar photovoltaic power can be cut in half by 2030, with total solar PV installations reaching 200,000 megawatts.[102]

In addition to reducing demand for fossil fuel and nuclear power generation, solar PV provides additional economic value by lessening strain on the electricity grid. As a form of "distributed generation," solar PV reduces demand on the transmission grid by producing power close to where it is used. And because solar PV tends to generate the most power on hot, sunny days when electricity is in greatest demand, it reduces the need for expensive additions to the electric system to meet peak demand.

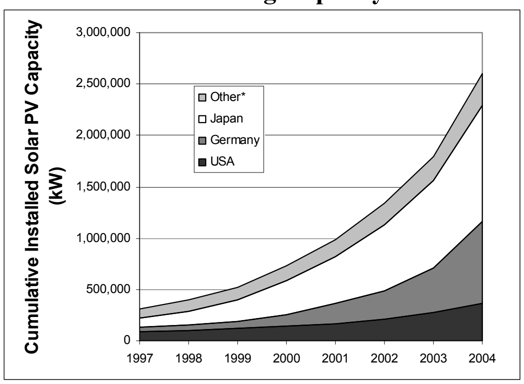
A variety of technologies exist that tap the energy of the sun, including:

- Traditional, silicon-based PV systems, which have come down in price and seen significant improvements in efficiency over the past two decades.
- Thin-film PV systems, which use technology similar to that in solar calculators and have the potential to eventually be produced more cheaply than traditional PV systems, since they are less reliant on high-grade silicon. But they require technological advances to increase their efficiency at turning sunlight into energy.
- Concentrating solar power plants, which use mirrors to focus sunlight on a receiving fluid, which is then used to power a generator or engine to produce electricity. Experimental concentrating solar power plants were built as early as the 1980s, but the technology is now drawing renewed interest from utilities in the Southwest, which have committed to more than 1,000 megawatts of new concentrating solar power capacity in just the last year.[103]
- Solar water heating systems that use the sun's energy to provide hot water for home or business use.

Solar photovoltaic panels have come down in price over the last several decades and are increasingly prized for their ability to provide power when and where it is needed most. Credit: DOE/NREL, Warren Gretz.

Like wind power, solar power installations have increased dramatically around the world in recent years. The amount of solar PV capacity installed worldwide nearly doubled between 2002 and 2004. The United States, which was once the unquestioned leader in solar power installations, now trails Japan and Germany in total PV installations.[104] (See Fig. 3.)

Fig. 3. Cumulative Installed Solar Photovoltaic Generating Capacity[105]



* "Other" includes other members of the International Energy Agency's Photovoltaic Power System Program.

Several U.S. states have begun to move aggressively to support solar power. The state of California, for example, recently launched an incentive program designed to bring 3,000 megawatts of distributed solar power on line within the next 11 years, while New Jersey is targeting 1,500 megawatts of solar power by 2020.[106]

A strong push to develop solar energy in the United States that couples aggressive public policy initiatives with research and development assistance could create economies of scale sufficient to bring the price of solar power to the "break even" point in the foreseeable future – thus making it possible for Americans to get a large share of their power from the sun.

Biomass Energy

Plants are efficient harvesters of solar energy and provide a large potential energy source for the United States. Biomass already supplies about 3 percent of the nation's energy, largely through the consumption of wood and wood waste.[107] Biomass can be obtained from a variety of sources – from crop residues to dedicated energy crops. In addition, methane captured as a result of the decomposition of landfill waste and animal manure can also produce biologically based energy.

As with other renewable resources, care must be taken in the development of biomass resources in order to ensure that harvesting of biomass does not create or encourage environmentally destructive practices and that the goal of using biomass for energy does not crowd out cultivation of crops needed to feed growing populations. We may also need to make choices about the best use of biomass – whether it is to replace fuel for automobiles or to provide power or products for industry. Even with these constraints, there is great potential for America to use biomass to reduce its dependence on fossil fuels.

The Biomass Technical Advisory Committee, which advises the U.S. Department of Energy on biomass issues, has set a series of targets for biomass development, including having biomass account for 5 percent of industrial and electric generator energy use and 10 percent of transportation energy use by 2020.[108]

Geothermal Energy

The earth itself provides a renewable source of energy through natural heat and hot water contained deep within the earth in some parts of the country and through the consistent temperature of the ground near the earth's surface across seasons in all parts of the United States.

Geothermal energy from deep underground sources of hot water has been used to generate electric power for decades, particularly in the Southwest. Unlike other renewable sources of energy, geothermal energy produces consistent, baseload power 24 hours a day. Utilities in the western United States have recently begun to ramp up their interest in geothermal resources, with plans for an additional 200 megawatts or more of geothermal capacity on the drawing board or under construction.[109]

New "enhanced geothermal" technology, in which water is injected into the ground where it is turned into steam through contact with hot rock, has the potential to expand the geographic range of geothermal power. Some estimate that as much as 100,000 megawatts of enhanced geothermal energy could be economically viable in the United States.[110]

Across the country there is great potential to take advantage of the naturally consistent temperatures near the earth's surface using geothermal heat pumps. At a distance of 10 to 12 feet below the earth's surface, temperatures generally remain about 55 degrees.[111] Geothermal heat pumps use the disparity between the consistent temperature of the earth and hot or cold air temperatures to reduce the need for fossil fuels to provide space heat or cooling to buildings. More than 1 million geothermal heat pumps are currently in use in the United States, but much of the market remains untapped.[112]

PUTTING IT ALL TOGETHER

The term "renewable energy" includes a wide variety of resources that can perform a variety of functions within America's economy – providing heat and light for our homes, fuel for our cars, energy for industry, and clean sources of electricity. Over the past two decades, several renewable technologies – most notably wind power – have become increasingly cost-competitive with fossil fuels, and continued technological advances and increasing economies of scale should lead to further price reductions in the years ahead.

The review of renewable technologies above demonstrates that the amount of energy available from the sun, wind, crops and earth is enough to power much, if not all, of America's economy. Harnessing and making use of that energy, however, is not a simple matter. America's economy and our infrastructure were built around fossil fuels. Transitioning to an economy that takes advantage of renewable energy will require us to reorganize our systems for producing, delivering and using energy. And that will require a strong commitment to the task.

Given the uncertainty surrounding some renewable energy technologies, it is difficult to forecast the precise recipe of renewable resources that can lead America to obtain 25 percent of its energy from renewables by 2025. But the options are many, and the technologies to capture that energy exist and are advancing quickly in their sophistication and economic competitiveness. With a firm goal driving the development of renewable resources and a strong public policy commitment, there is little reason to think that a 25 percent target for renewable energy could not be achieved.

THE NEXT WAVE: ENERGY FROM THE OCEAN

Since colonial days, America has tapped the power of moving water to power our economy. In those days, mills located alongside streams and rivers used the power of water to operate machinery. Hydroelectric dams, while environmentally problematic, are now the number two source of renewable energy in the country, just behind biomass.[113]

But there is a large source of moving water that has not yet been effectively tapped for energy: the ocean. The amount of energy available is immense; the power of waves breaking on the world's coastlines has been estimated at 2 to 3 million megawatts, and further energy is available from the regular movement of tides.[114] New technologies finally offer the potential to harness energy from waves and tides, potentially providing an important energy source for coastal cities.

A variety of technologies are available for tapping wave energy, from devices that look like floating corks and noodles to structures built into the shoreline that use wave motion to generate electricity.[115] Prototype wave energy devices have been tested off the coasts of Hawaii and New Jersey, and one company has proposed a wave energy project off the coast of Oregon that could eventually be scaled up to produce 50 megawatts of power.[116]

Tidal energy, on the other hand, is captured through the use of underwater turbines similar to wind turbines. A proposal to install several

Turbines like the ones in the diagram above could be used to harness the power of tidal energy. Credit: Marine Current Turbines.

turbines in the East River of New York City could come to fruition soon, eventually resulting in the generation of 10 megawatts of power.[117] At least 11 other tidal projects nationwide have been conditionally approved and more than 20 others are under consideration.[118]

Wave and tidal energy are relatively new technologies and need to be fully evaluated for their environmental impacts. But they represent yet another promising source of additional renewable energy.

The Role of Research and Development in Achieving a New Energy Future

In the 1970s, as Americans scrambled to react to rising energy prices, the federal government responded in a number of ways. One of those responses was to dramatically ramp up investment in federal energy research and development programs.

The research and development efforts of the 1970s are still benefiting Americans today every time we plug in a highly efficient refrigerator or install energy-efficient windows in our homes. But as energy prices declined in the 1980s, the United States slashed spending on energy research and development programs. One is left to wonder what clean energy technologies might be in the pipeline today if our investment in clean energy research and development had continued.

With more energy challenges facing America today, we cannot afford to make the mistake of short-changing efforts to discover and develop the next wave of clean energy technologies. Instead, we should dramatically ramp up our investment in research efforts to reduce our consumption of energy and increase our ability to tap into America's vast renewable energy resources. That investment should be geared toward meeting the specific goals for energy efficiency improvements, oil savings and renewable energy development contained in the New Energy Future platform.

The United States should commit to a goal of investing $30 billion over a 10-year period in energy efficiency and renewable energy R&D programs. Although this investment would represent only a small fraction of the total federal budget, it would go a long way toward securing a new, sustainable energy future for America.

The Benefits of Federal Clean Energy R&D

Research and development is a long-term process with no guarantee of success. It can take 20 to 30 years between the commencement of basic research on a technology and its arrival on the market.[119] And there is no guarantee that an investment in research in a particular technology will ever "pay off" in a marketable product.

Nonetheless, federal energy R&D activities have played an integral role in bringing several cutting-edge clean energy technologies to market. For example, federal spending on just six energy efficiency technologies – advanced refrigeration compressors, electronic ballasts for fluorescent lamps, low-e glass for windows, advanced lost-foam casting, oxygen-fueled glass furnaces, and advanced turbines – has yielded about $30 billion in economic benefits on an R&D investment of about $400 million – a return on investment of 75 to 1. Those six technologies have saved approximately 5 quadrillion BTUs of energy, equivalent to about 5 percent of America's annual energy use.[120]

Energy-saving refrigerators and concentrating solar power plants are two examples of how strategic federal spending on R&D can yield big benefits.

Concentrating solar power technologies, like this dish-engine system, have made great advances thanks to federal research and development efforts. Credit: DOE/NREL, Stirling Energy Systems.

The modern refrigerator represents one of the most remarkable achievements in the field of energy efficiency. Today's refrigerators use approximately two-thirds less electricity than those built in 1974, even though today's models are, on average, bigger, have more features, and do not include ozone-depleting substances.

While many institutions were involved in that achievement, the Department of Energy's (DOE) research and development efforts played a critical role, starting with the 1977 launch of a program to improve the energy efficiency of appliances. The DOE's initial investment of $775,000 helped demonstrate the feasibility of a full-featured refrigerator using 60 percent less electricity than comparable conventional units and produced new computer tools for analyzing the energy-use implications of refrigerator design options. DOE's research and development program and partnerships also played a key role in allowing industry to phase out ozone-depleting hydrochlorofluorocarbons (HCFCs) without an energy penalty. Lastly, DOE funded R&D by a leading compressor manufacturer to improve compressor efficiency. The resulting, more efficient compressors were responsible for about half of the refrigerator efficiency improvement during the 1980s.[121]

Federal investment in concentrating solar power (CSP) hasn't yet yielded the kind of substantial economic benefits delivered by the refrigerator program, but it is an example of how investment in a novel technology can create benefits decades down the road.

CSP technologies use mirrors to concentrate the sun's energy to produce electric power with conventional turbines or heat engines. CSP was conceived of as a means to harness the sun's energy to provide large-scale, domestically secure, and environmentally friendly electricity. In the aftermath of the energy shortages of the 1970s, federal R&D programs rapidly advanced the technology, leading to early commercial implementation of CSP in the mid-1980s. As energy prices declined during the 1980s, commercial interest in CSP waned, but research and development efforts did not stop – making incremental advances in system performance, reliability and cost over time.[122] As a result, the cost per kilowatt-hour of CSP was cut by two-thirds and the industry has a goal of cutting costs in half again by 2015. [123]

These advances have brought CSP to the brink of wide-scale commercialization, with utilities in the Southwest committing to more than 1,000 megawatts of new concentrating solar power capacity in just the last year.[124] Researchers at Sandia National Laboratory believe that additions of up to 20,000 megawatts of new CSP capacity could come on line by 2020.[125]

The Need for Increased Clean Energy R&D

Despite this legacy of success, funding for energy research and development has stagnated in recent years. After reaching a high point of $8 billion in 1980, the United States now spends, on average, less than half that amount (only $3 billion per year) on all energy R&D programs in both the public and private sectors.[126]

Federal spending on renewable energy research and development peaked in fiscal year 1979 at $1.4 billion (in 2003 dollars). By fiscal year 1990, the renewables R&D budget had been slashed by nearly 90 percent. Although funding for renewables R&D rebounded to more than $400 million in fiscal year 2003, we still spend only about one-third as much money on renewable energy research as we did in the late 1970s.[127] Federal funding for energy efficiency R&D followed a similar path, with funding slashed by about two-thirds during the 1980s. In fiscal year 2005, Congress appropriated $584 million for energy efficiency R&D, 15 percent less than was spent in fiscal year 1980.[128]

Clean energy R&D programs continue to face relentless budget pressure. The fiscal year 2007 federal budget adopted by the House of Representatives in May includes increased spending for research funding into hydrogen fuel, biomass and solar power. But it also includes dramatic reductions in research for geothermal energy, advanced materials for vehicles, and small-scale hydroelectric power. The budget also eliminates the Department of Energy's building codes program.[129]

Perhaps no recent event drew more attention to the low level of priority given to clean energy research than the 2005 decision by the National Renewable Energy Laboratory to fire 32 employees, including eight researchers, in order to fill a $28 million budget gap.[130] The employees were eventually reinstated, but the idea that researchers working on alternative energy supplies could be let go in the midst of a nationwide energy crunch symbolized the inadequate and tenuous funding currently provided to clean energy research and development.

The current federal investment in clean energy technologies is a pittance compared to the nation's overall spending on fossil fuels – or the multi-billion dollar payoff that could result from the development of a new cutting-edge clean energy technology.

The time has come to make a large and sustained commitment to development of the next generation of clean energy technologies by committing $30 billion over 10 years to research and development efforts to advance energy efficiency and renewable energy. The research and development effort should be focused on achieving the goals of the New Energy Future platform. While many areas of technology could benefit from an infusion of research and development funding, the following areas could be fruitful topics for study:

- **Technology refinement and improvement** – Renewable energy technologies like wind and solar power have made tremendous advances over the past few decades, but there is still much room for improvement. For example, as mentioned above, thin-film solar photovoltaic systems have the potential to be produced more cheaply than traditional crystalline silicon systems, but currently do not achieve similar efficiency in converting sunlight to electricity. We already know how to make ethanol from corn, but need to develop and improve technologies for converting energy crops and plant residues to fuels. Federal R&D efforts have already helped increase the efficiency of thin-film PV systems and are beginning to make inroads on the production of ethanol from new sources, and further efforts could result in additional improvements. Many other renewable energy and energy efficiency technologies – from geothermal energy to wind energy, and from efficient appliances to efficient vehicles – could benefit from similar incremental improvements.

- **Technology integration** – Clean energy technologies don't exist in a vacuum. Rather, they must gain a foothold within a marketplace that is currently geared toward the use of fossil fuels. The difficulty of the transition from idea to market is exemplified by the challenges faced by alternative fuel vehicles, which face a classic "chicken-and-egg" problem: no one will buy a vehicle that can't be refueled, yet no investor will build a fueling station if there are no vehicles to use it. Thus, research and development efforts also need to be focused on the technologies that make it possible for America's economy to accommodate clean energy resources. For alternative fuel vehicles, that might mean conducting research that will improve the storage and delivery of hydrogen fuel or ethanol. For renewable sources of electricity, it might mean conducting research into ways to store energy generated from wind turbines or to seamlessly integrate solar photovoltaic panels into the electric grid. And for energy efficiency technologies, it might involve research into ways to deliver the same or better functionality in equipment or appliances that use far less energy.

- **Production** – High production costs can hamper the economic competitiveness of clean energy technologies. Research and development can focus on helping industries produce those technologies more cost-effectively, and developing ways to make the quantum leap from small-scale production of those technologies to mass production.

- **Demonstration and deployment** – Once a promising technology has been developed in the laboratory, it is important to test out how the product works in the "real world," to fix problems that are identified in those tests, and to identify effective strategies for the deployment of the technology in the marketplace. Federal R&D efforts can also play an important role in identifying likely markets for clean energy technologies and developing effective strategies for entering those markets.

- **Mitigating environmental and social impacts** – All energy producing technologies have some impact on the environment and society. Some of those impacts are well understood at the time the technologies are developed and others become apparent only after they are in use. Federal research and development programs should include efforts to identify and mitigate those impacts, so that the transition to a clean energy economy produces the maximum benefits for society.

- **New technologies** – No one would suggest that we have identified or begun to tap all of the many possible sources of renewable energy or energy efficiency that exist in America. One of the most important roles of research and development is to follow up on promising leads for brand-new technologies, such as the wave and tidal energy technologies mentioned earlier in this paper. Investment in these untried technologies is risky and will yield as many failures as successes. But as the example of concentrating solar power demonstrates, early investment in a promising new technology can provide benefits years or decades down the road.

R&D Is One Piece of a Larger Puzzle

Adequate funding for research and development is a necessary element of achieving a New Energy Future. But it is not sufficient. The federal research and development effort described here must be *focused* on specific goals for reducing dependence on fossil fuels and be *supported* by aggressive public policies that ensure that the energy-saving products developed in the laboratory find their way into America's economy.

Research and development must work hand in hand with public policies such as strong energy efficiency standards. For example, the advances in refrigerator energy efficiency described above were made possible by technological breakthroughs by DOE and industry researchers. Those advances, in turn, made it possible for California, and later the federal government, to impose aggressive energy efficiency standards for refrigerators. It was those standards – and not the original research and development effort – that ensured that more energy efficient refrigerators eventually found their way into American homes.

The opposite circumstance occurred in the 1990s with regard to federal efforts, in partnership with American automakers, to develop a prototype 80 mile-per-gallon car. While the Partnership for a New Generation of Vehicles (PNGV) did result in technological improvements that improve fuel economy, the effort was not matched with any accountability mechanisms or regulatory drivers, such as more stringent federal fuel economy standards, that would have ensured that those technologies actually found their way into vehicles. Ironically, federal spending on PNGV may have actually *hurt* American automakers by stimulating their Japanese competitors, Honda and Toyota, to ramp up their own research into the development of more fuel-efficient vehicles. Those efforts culminated with the 1997 introduction by Toyota of the world's first mass-market hybrid-electric vehicle in Japan and the later introduction of hybrids to the U.S. market in 2000.[131] American automakers have been playing catch-up with their Japanese counterparts ever since.

Conclusion and Recommendations

There are a wide variety of technologies that can enable the United States to achieve the goals of the New Energy Future platform. And America should invest in developing more and better clean energy technologies by increasing its investment in energy research and development.

But clean energy technologies are not of much use if they aren't integrated swiftly and broadly into our economy. Public policy can play a crucial role in making that technological transition happen.

The first step is for America to set specific, ambitious goals for its energy future. The New Energy Future platform represents just such a set of goals, calling on America to:

- **Reduce our dependence on oil** by saving one-third of the oil we use today by 2025 (7 million barrels per day).
- **Harness clean, renewable, homegrown energy sources** like wind, solar and farm-based bio-fuels for at least a quarter of all energy needs by 2025.
- **Save energy** with high performance homes, buildings and appliances so that by 2025 we use 10 percent less energy than we do today.
- **Invest in a New Energy Future** by committing $30 billion over the next 10 years to the New Energy for America Initiative, thus tripling research and development funding for the energy-saving and renewable energy technologies we need to achieve these goals.

The next step is for America to adopt a suite of public policies sufficient to achieve those goals. A comprehensive list of policy options is beyond the scope of this report, but the following policies would represent a strong first step:

Energy Efficiency in Homes, Business and Industry

- Set strong energy efficiency standards for household and commercial appliances.
- Strengthen residential and commercial building codes and ensure that they are adequately enforced.
- Require utilities to meet growing energy needs through energy efficiency improvements before building new power plants.
- Expand and invest in energy efficiency programs to help homeowners and businesses install the latest technologies in their homes and businesses.
- Eliminate obstacles to the use of combined heat and power (CHP), which would dramatically improve opportunities for industrial and commercial energy efficiency.

Oil Savings

- Increase fuel economy standards for cars, light trucks and SUVs to 45 miles per gallon over the next decade and a half and set strong fuel economy standards for heavy-duty trucks.
- Set goals for the use of plant-based fuels like ethanol and biodiesel and enact policies that ensure that those fuels are developed cleanly and sustainably.
- Invest in expanded and improved public transit service, promote "smart growth" practices that reduce the need for driving, and encourage other transportation choices like telecommuting, carpooling, biking and walking.

Renewable Energy

- Enact a national renewable energy standard, similar to those already in place in 20 states, that would require a minimum percentage of the nation's electricity to come from renewable sources.
- Increase research and development funding to develop the next generation of renewable energy technologies.
- Provide consistent, long-term tax incentives for the installation of solar panels and other forms of renewable energy.
- Require utilities to prioritize renewable energy development over the construction of conventional power plants to satisfy electricity demand.

Notes

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[2] This goal reflects a target set by the bi-partisan Set America Free coalition, www.setamericafree.org.
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