White Paper

America’s Energy Choices

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In Brief:

- America needs more energy of all sorts, but especially electricity.
- By 2035, U.S. electricity demand will increase by 30%.
- By 2050, all present U.S. electricity-generation power plants will need to be replaced.
- We have to make choices on what energy mix we need in the future – the present situation is *geopolitically*, *environmentally*, and *economically* unsustainable.
- America’s energy choices should be considered in light of three concerns:

  - Energy Security

  - Economic Stability

  - Environmental Sustainability

- There are three broad categories of energy to choose from: Fossil Fuels, Nuclear Energy, and Renewable power. Within each of these categories are a broad range of choices, each of which will have positives and negatives in each of the three areas.

The following paper lays out the facts, matching the 10 most important energy choices to the concerns to allow policy makers to make informed decisions.

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America's Energy Choices

Thirty-seven years ago, President Richard Nixon announced a national goal that by "the year 1980, the United States will not be dependent on any other country for the energy we need to provide our jobs, to heat our homes, and to keep our transportation moving."[1]

Since this 1974 State of the Union address, given in the midst of an embargo of oil exports to the United States and its allies, some sort of 'energy independence' has been a stated policy of every Presidential administration. Regardless of this rhetoric, however, the United States has not come anywhere near 'energy independence.'

Today, energy policy is back at the center of national affairs. Partly this is because once again, for the second time in three years, the global price of oil has jumped to near-record territory.

The urgency of the energy debate today, however, is about more than simply gasoline prices. Environmental concerns are bringing the very basis of America's energy system into question: the evidence that human fossil fuel use contributes to climate change becomes more unequivocal every day.

America's foreign policy is constrained by questions of energy security, as support for democratic revolutions across the Arab world has to be balanced by a preference for stability in the major oil producing nations around the Persian Gulf.

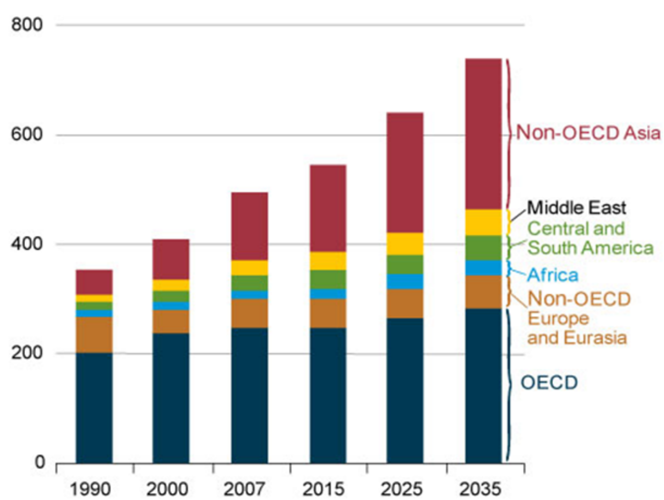
Energy infrastructure across the United States is showing its age as the power grid struggles to meet demand and power plants near retirement. Meanwhile, advances in new technologies hold the promise of plentiful energy requiring little or no fuel; but significant research funding is required.

Policymakers will have to address these challenges while also providing for a 20% increase in total energy demand across the United States, including a 30% increase in electricity demand by 2035. All of this will happen in a world where total energy demands are expected to increase by 50%, driven by unprecedented economic growth in developing countries such as Brazil, China, and India.

These challenges are significant – but none of them are a question of yes or no, either/or, do or do not. Instead, how the United States meets those challenges will require choices – strategic decisions about infrastructure investment, government policy, research funding, and even foreign policy.

These challenges cannot be met by slogans or political sound-bites. These are important decisions requiring an informed and wide-ranging debate – not trench warfare over small issues. The time for rhetoric and posturing on energy issues is swiftly approaching its end. The time for action, or the consequences of inaction, is approaching.

Figure 50. World energy consumption by region, 1990-2035 (quadrillion Btu)



Source: EIA Annual Energy Outlook 2011, http://www.eia.gov/forecasts/aeo/MT_intl.cfm

Assessing America's 21st Century Energy Choices

Today, the United States faces a series of choices that will determine how its economy is powered to meet the needs of the 21st century. How America chooses to replace and expand its energy supply will affect the health of the world's environment, America's national security, and the well-being of the U.S. economy. However, the political debate does not have an effective vocabulary to discuss the costs and benefits of different choices.

Policymakers too often make arguments about energy based on which will 'sell' the best in order to fit a decision already made. Instead, policymakers should look at the options and weigh the tradeoffs for each. Because there are tradeoffs – decision makers should not pretend there are silver bullets that will automatically bring cheap, clean, domestic energy to all.

This paper will attempt to outline a matrix of policy choices for the government, utilities, and the private sector to consider.

It will look at ten different options for how to fuel America's economy, each of which will be considered in light of three concerns:

(1) Energy Security;

(2) Economic Stability; and

(3) Environmental Sustainability.

Sometimes these terms are simply buzzwords, so it is important to specifically define each.

Energy Security

Analytically, 'energy security' is difficult to quantify. President Jimmy Carter defined energy security in a 1977 speech as "independence of economic and political action" in international affairs.[2] The United States should be able to define its interests overseas independently from how it uses energy domestically.

Importantly, 'energy security' does not mean 'energy independence' in the sense that all of the energy used in the United States comes from within its borders without international trade. This is neither obtainable nor desirable in a globalized world. In addition, energy security does not depend on the percentage of supply that is imported. In a world of globally traded commodities, it is no longer possible to be truly energy independent: even domestically produced energy sources are subject to fluctuations in global commodity markets.

Since the oil price crises of the 1970s, the risk of absolute supply shortages has been reduced significantly. The creation of the International Energy Agency (IEA) and its requirement that all member countries hold oil stocks capable of replacing 90 days' worth of imports acts as a buffer against disruptions in oil supplies. The U.S. Strategic Petroleum Reserve can substitute for, on average, 75 days' worth of oil imports as of June 2011, and privately held reserves account for the additional days of imports.[3]

Although speculators are sometimes blamed for inflating prices, the deepening of international futures trading markets allows price signals to give warnings of impending supply and demand imbalances. Today, then, for the United States, energy security concerns are no longer about physical disruptions in supply. These concerns stem from the possibility that actions in foreign policy will lead to price increases causing undue harm to economic growth.

Keeping this is mind, this paper defines energy security as the ability for a country to act in its foreign policy independently of how it uses energy domestically.

Obtaining energy security actually does not come from increased domestic production alone: it comes from flexibility, competition, and redundancy. If a source of energy supply is easily replaced by either a different fuel type or a different source, then a country is insulated from supply shocks. U.S. foreign policy should be determined by its interests, not by how it generates its energy.

Economic Stability

It seems clear that all decisions about energy policy must consider price. The United States, though, is one of the most energy intensive developed economies, which makes its economy vulnerable to price fluctuations.

Low prices at the expense of little buffer against fluctuations in price – both up and down – can be more harmful than a higher price that is stable over the long-term. Upward price shocks harm consumers by acting as a tax, but downward price shocks can harm producers as well by undermining long-term investments.

When prices are low, consumers are encouraged into dependency, only increasing the economic damage if prices spike upwards. The best example of this is that today, American drivers are feeling the pain of gasoline-dependency that years of low prices created.

When decision makers are deliberating about energy choices, the relative price of each decision is a critical component. However, short-term fuel prices cannot be the reason that long-term decisions are made. When deliberating on an energy choice, its economic stability – defined as how energy affects the health of the country's economy over the long term – should be an important concern. Producers and consumers should be able to make rational economic decisions independently of price fluctuations or negative externalities from energy.

Therefore, it is more important for an energy choice to be made that will provide long-term economic stability rather than providing only for low prices at any expense, particularly if those prices tend to be volatile.

Economic stability should be prioritized above low prices because the pursuit of low prices can give license to producers to ignore other costs. By ignoring these externalities, particularly pollution, the pursuit of low prices can cause non-economic costs to arise elsewhere, for example in reduced health from polluted air and water.

Environmental Sustainability

While there remains a deep political divide in this country (and few others) about whether man-made emissions are causing the climate to change, the debate in the scientific community is no longer about whether humans are causing climate change, but how much those emissions are hurting.

The most controversial debates among scientists are about the sensitivity of the climate to increased concentrations of greenhouse gases. However, even if policymakers are skeptical of the scientific basis for the theory of climate change, a prudent, precautionary course in the face of uncertainty would demand that some action be taken.

After the 2008 election, in which both Barack Obama and John McCain supported government policies to cap and ultimately reduce greenhouse gas emissions, environmentalists had hoped that the U.S. Congress would address the problem of climate change. However, the problems of a major recession, shifting stances on the truth behind climate change, and competing legislative priorities meant that the Waxman-Markey bill to cap greenhouse gas emissions – passed by the House of Representatives in June 2009 – was never taken up by the Senate.

Even though there is no domestic law limiting carbon emissions, the U.S. Government, under both Presidents Bush and Obama, has committed to a number of international agreements to cap and reduce emissions, expressed through statements at the G-7, the G-20, and the UN's Copenhagen Accord.

Climate change has deep implications for energy policy. The fossil fuels the United States uses to produce 83% of its energy are the main driver of climate change.[4] Therefore, any plan that looks to reduce emissions will require either reducing the total amount of energy produced (either through gains in efficiency, or absolute declines in energy used) or replacing a large portion of energy production with emissions-free power.

As the world's second largest emitter – about 5,360 tons of carbon emitted from energy generation in 2009 (19% of global emissions)[5] – the U.S. will play an important role in determining whether the world can successfully prevent dangerous climate change.

Environmental sustainability is about more than climate change, however.

Local environmental effects of energy production are as important – or more – than climate change to how the United States makes its decisions about energy production. Decisions on how strictly to legislate and enforce pollution limits have significant impacts on decisions about how to produce energy. Environmental sustainability in energy generation and extraction are critical to the feasibility of any energy system.

The extraction, through mining or drilling, of fuels and minerals necessary for energy production can have negative effects on the local environment. These externalities include spills, water contamination, and air pollution – all of which can be harmful to the health of people living and working around extraction sites. How energy production affects local water supplies and local air quality will determine how the public accepts new energy developments.

An energy source should be defined as environmentally sustainable if the production and use of it does not cause undue harm. Whether that harm is to local ecosystems, the global atmosphere, water systems, neighboring businesses, or human health, an energy source with substantial externalities is not sustainable over the long term.

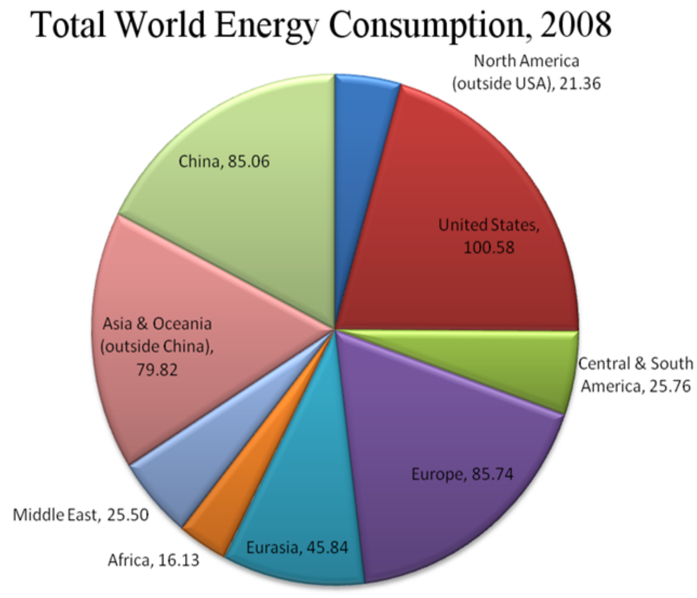
Environmental sustainability and economic stability are closely linked over the long-term, because an energy choice that harms the environment will eventually cost more. It may be true that polluting can reduce costs, just as throwing garbage out an apartment window is cheaper than paying for garbage collection, but over the long-term both will prove unsustainable. This is because political, regulatory, and legal pressure will be brought against pollution sources to both reduce effluence and clean up any contamination.

When making a choice of how to power the American economy for the future, decision makers should clearly articulate how each potential source of energy affects national energy security, economic stability, and environmental sustainability.

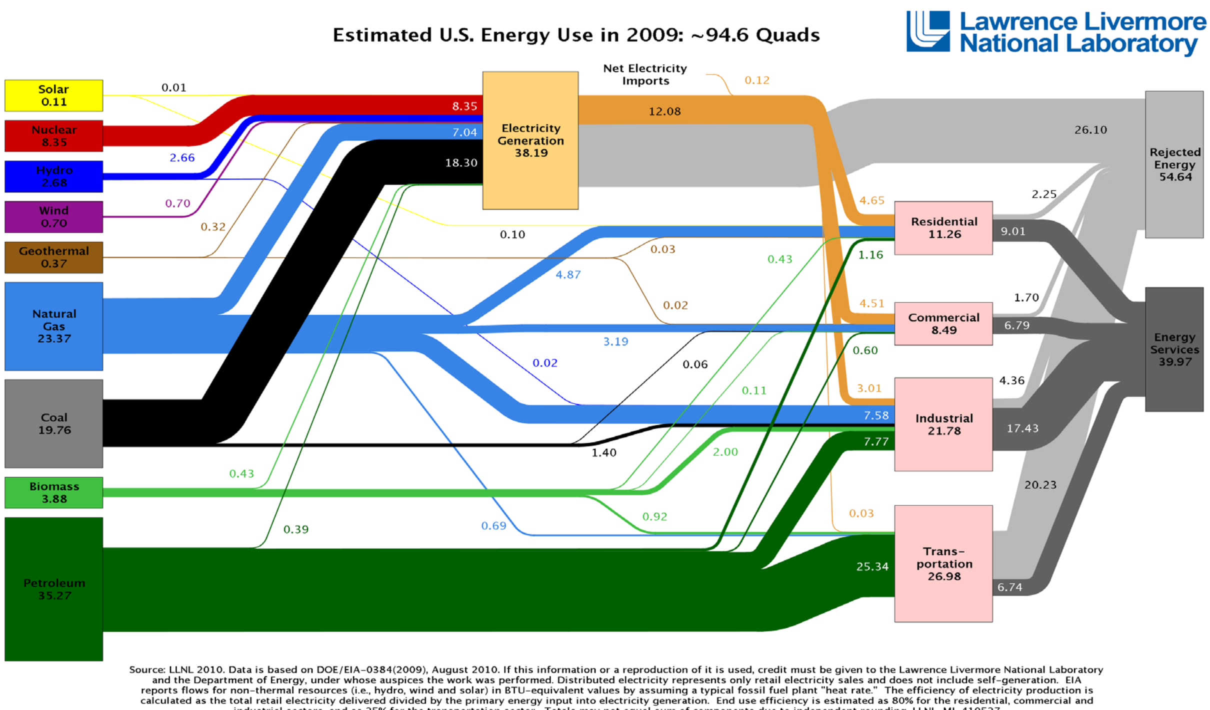
Options for America's Energy Use

According to the IEA, the United States is the world's largest user of energy, consuming 18.6% of the global annual energy supply in 2008.[6]

A description of America's future energy choices must begin with how the United States uses and produces energy now. Lawrence Livermore National Laboratory's flow chart (Figure 1) shows how the U.S. energy use in 2009. This chart shows the relative size and importance of each source of energy, as well as how each energy type is used. Analyzing the chart leads to some important conclusions, such as the separation of energy between that used for electricity generation and that used for transportation and the staggeringly high amount of 'rejected' (wasted) energy. The major drawback of the chart is that it is a static snapshot of energy use – it does not show growth or decline over time. Nevertheless, it provides an important baseline for the discussion of the different fuel types that follows.



Source: EIA International Energy Statistics, http://www.eia.gov/cfapps/ipdproject/IEDIndex3cfm?tid=44&pid=44&aid=2



Source: Lawrence Livermore National Laboratory, https://flowcharts.llnl.gov/

I. Fossil Fuels

Fossil fuels make up the largest portion of energy production in the United States. Petroleum products, coal, and natural gas accounted for 83% of total energy production in 2009. Each has different physical properties that have given them very different roles in America's current energy mix.

It is not a mistake that fossil fuels are the dominant sources of fuel in the industrialized world. The combination of low prices and high energy density have made first coal, then oil and natural gas, the preferred choices for energy production for over 200 years. This long-term usage gives those fuels two centuries of built-in advantage in the form of infrastructure built to use and transport these fuels. It is not enough to say that because fossil fuels are cheap, they always will remain the best choice.

Rising global demand for all sources of fossil fuels is driven by population growth and the requirements of a burgeoning middle class in developing countries. Meanwhile, although geologists, economists, and analysts continue to argue about how much coal, oil, or gas remains beneath the ground, by definition, supplies of fossil fuels are finite.

Together, increases in demand coupled with constrained supply will inevitably lead to price increases. It is only a question of when fossil fuels are no longer the economical.

These three major fossil fuels all present significant, though different, challenges to American energy security, economic stability, and environmental sustainability.

Since the very beginning of the industrial revolution, when the cities of England were turned black by coal soot, it has been clear that burning fossil fuels have a cost to the local environment. This pollution is not only dangerous to ecosystems and wildlife; it has also proved to be detrimental to human health. In the United States, industrial pollution from fossil fuels was one of the main reasons for the creation of the Environmental Protection Agency.[7]

Over the last thirty years, advances in technology, such as the catalytic convertor on automobiles and advanced scrubbers in power plants, have reduced the amount of toxins released into local air and water supplies. However, it is only within the last thirty years that scientists have begun to prove that the emissions from fossil fuels, especially carbon dioxide, are also causing the climate of the entire Earth to change. So far, there is no technical fix to this: the only way to prevent fossil fuels from emitting greenhouse gases into the atmosphere is to not burn them at all.

The result of two centuries of increasing fossil fuel use is that the concentration of carbon dioxide in the earth's atmosphere has risen by 4% from about 275 parts per million (ppm) to a record 391 ppm in 2011 and that the Earth's average temperature has risen by about one degree Celsius.[8]

The United States has a responsibility as the second largest emitter of greenhouse gases in the world to reduce its emissions. Innovation and new technologies are increasing the efficiency of the engines and power plants that burn fossil fuels – meaning that less fuel and fewer emissions will produce the same amount of energy.

However, any efforts to reduce emissions must realize that you can only go so far with fossil fuels. If 83% of America's energy continues to come from fossil fuels, then the earth would likely be stuck on a trajectory of warming 3 or 4 degrees above pre-modern levels – far beyond what climate scientists have deemed as a safe level.[9]

1. Oil

Oil accounts for 35% of total energy use. While very little of that is used to produce electricity, it is the dominant fuel for transportation: 94% of the energy that powers American cars, trucks, trains, and planes comes from burning fuels refined from crude oil in an internal combustion engine.

The dominance of oil for transportation comes from its unique physical properties that make it well-adapted to transportation: it has a higher amount of energy per kilogram than coal, but because it is in a liquid form, it is easily transportable, unlike natural gas which requires specialized containment.

Oil also enjoys an effective monopoly on transportation because its century-long dominance of transportation has resulted in a large and efficient infrastructure dedicated to extracting, refining, and distributing crude oil and the fuels that are refined from it.

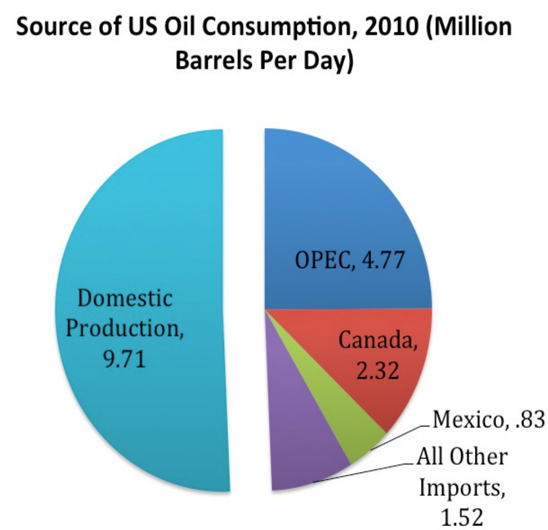
Energy Security

For the United States, dependence on oil for its transportation is a direct threat to energy security; concerns about the impact on the price of oil are an important factor in foreign policy decisions.

The United States produces more than half of the oil it consumes (net imports are 47% on consumption) with 20% of imports coming from its NAFTA neighbors of Canada and Mexico, but the price consumers pay for oil depends on global markets.[10]

Even if the United States could produce 100% of the oil it used, American consumers would still be vulnerable to global price fluctuations based on supply disruptions in unstable regions. For example, the rise in oil prices due to the Spring 2011 revolution and civil war in Libya have impacted American consumers, even though Libyan oil exports to the U.S. compose less than 1% of all imports in 2010.[11] Integrated global oil markets mean that producing more oil within the United States will not erase security threats.

So long as 30% of global production comes from the Middle East (12% from Saudi Arabia alone, or 10 million barrels per day) and so long as it has over 50% of the world's total proven reserves, American foreign policy in the region will continue to follow the Carter Doctrine.[12] First promulgated in 1979, it states that because of its oil reserves, "an attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States."[13]



Source: EIA, Petroleum and Other Liquids, http://www.eia.gov/petroleum/data.cfm

Economic Stability

U.S. dependence on oil for transportation harms its economic stability as much as it harms its energy security. In addition to the long-term problems of supply and demand, oil suffers from the short-term problem of price volatility. Over the last four years alone, the global price of oil has fluctuated from an average price per barrel of $69 in 2007 to a peak of $147 in July 2008, back down below $35 in January 2009, then back up above $120 per barrel in April 2011.[14] This constant fluctuation harms consumers and businesses because it impairs their ability to plan for the long-term.

A second problem of economic stability in America's reliance on oil is the dependence on imports.

The United States sends hundreds of billions of dollars overseas to pay for oil. The United States consumed over $1.45 trillion worth of oil in 2010, of which $680 billion was spent on imports.[15] Without these imports, the U.S. trade deficit, which was $497 billion in 2010, would not have existed.[16] That capital could be used for investment at home. The export of this capital has the effect of driving down the value of the dollar. Coupled together, volatility and import dependence mean that rapid price increases act as a tax increase on consumers – but instead of this tax increase being used to pay down the budget deficit or invest domestically, 50% of it is sent overseas.

Environmental Sustainability

Greenhouse gas emissions from oil and petroleum products are single largest source of carbon emissions in the U.S.[17]

Oil produces 164,000 pounds of carbon dioxide emissions per billion British thermal unit (Btu) of energy -- 40% more than natural gas, but 21% less than coal.[18]

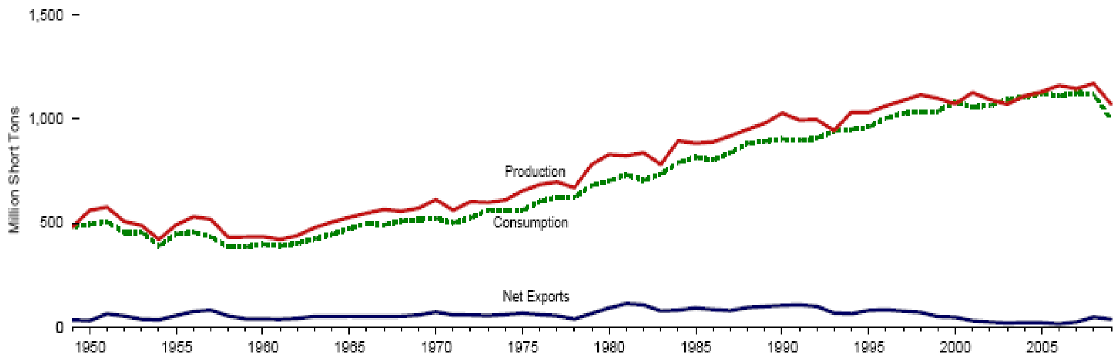
The U.S. government has instituted policies, such as the increase in Corporate Average Fuel Efficiency (CAFE) standards, which will reduce the amount of greenhouse gas emissions per mile traveled. This policy will produce technological options for reducing greenhouse gas emissions by improving automobile efficiency and by incentivizing automakers to look for cleaner or more efficient fuels – such as ethanol or biodiesel.

Although producing oil domestically is good for economic stability, there is a tradeoff. Drilling for oil can produce oil spills, like the explosion of the Deepwater Horizon platform in 2010 which killed 11 workers, shut down fishing across the Gulf of Mexico, and could ultimately cost $20 billion to clean up.[19]

As exploration for oil expands into more difficult-to-access areas, such as deep underwater, in the Arctic, or in the oil sands of Alberta, Canada, it is clear that there will be a greater risk of environmentally damaging spills due to the technical complexity of operating in these areas.

The American public will have to make a choice of whether it accepts the risks of environmental damage from increased drilling. Politicians and the public should not be surprised when future accidents happen – instead proper risk management procedures should be followed to minimize both the risk of an accident and the cost when one does happen.

2. Coal



Source: U.S. Coal Overview 1949-2009, EIA, http://www.eia.gov/coal

Coal provides 21% of total energy use in the United States and is the single largest source of electric power, providing 48% of electricity generation. Only about 7% of coal is burned for anything other than the production of electricity - mostly for industrial uses such as steel production.

In the United States, the largest states for coal mining are Wyoming and West Virginia, which annually produce more than half of all domestic coal.[20] About $1.5 billion worth of coal is imported every year, although the U.S. runs a trade surplus in coal, with about three times that amount exported.[21]

Energy Security

Coal, unlike oil, is almost entirely produced from domestic mines, and does not present the same security threats as oil. Moreover, unlike oil, coal is not been an easily tradable commodity, due to its size and weight.

The value of coal to American energy security is evident from the high priority that presidents from both parties gave it during the 1970s energy crises: Presidents Nixon, Ford, and Carter all initiated policies that favored domestic coal production for electricity generation.

The United States is estimated to have 249 years of recoverable coal reserves at present rates of consumption. Coal would be a nearly optimal choice, for purely energy security reasons, were it not for the fatal flaws of its environmental and safety record, which will be expanded on further in sections below.[22]

Economic Stability

The dominance of coal in utility-scale electricity generation is because mining and transporting it has historically been cheap.

Since the 1970s, technological advancements allowed for the construction of large, high-volume, coal power plants with higher thermodynamic efficiency than older plants, so that more energy to be converted to electricity and less wasted as heat.

For example, the largest coal power plant in the country - the Rockport plant in Spencer, Indiana - is capable of producing 2600 MW of electricity, twice the capacity of an average American nuclear power plant.[23] It uses over 9 million tons of coal per year.

However, the long-term cheapness of coal as a source of electric power may be beginning to come to an end. Railroads transport most coal production, and increasing demands on track along with industry consolidation mean that they can increase delivery prices of coal; for some coal deliveries, transportation costs account for 50% of the price of delivered coal.[24]

Environmental Sustainability

The price of cheap coal is apparent in visits to mining country, where mountaintops have been removed and people are less healthy. Coal mining remains the 7th most dangerous job in the country.[25]

Burning coal is the worst option for greenhouse gas emissions, producing 208,000 pounds of carbon dioxide emissions per billion btu of output.[26] Coal also contains pollutants, including mercury, lead, and sulfur. Many of these pollutants can be removed in the smokestack by modern scrubber technologies. However, there is not yet a technological fix for reducing greenhouse gas emissions.

There are pilot projects in Norway and Germany that are testing carbon capture and sequestration (CCS) technology as a way to remove greenhouse gas emissions and sequester them underground. They have not yet demonstrated that this is a safe, long-term option. It also is possible that the energy lost by capturing and sequestering the carbon dioxide will make coal power plants with CCS technology more costly and inefficient than competing power plants.

Coal may also be the worst option for the environmental and human damage it causes when it is mined. Coal mining releases toxic sulfuric acid into local groundwater supplies, destroys local ecosystems, and harms human health. Greater environmental regulations and the increasing use of coal from Wyoming's Powder River Basin, which has less average sulfur content than Eastern coal, mean that these new coal power plants do not emit as many acid-rain causing pollutants.

3. Natural Gas

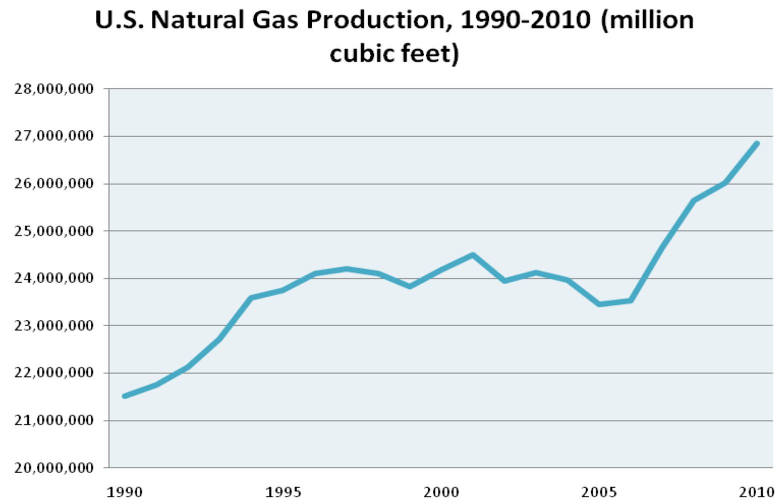
Natural gas provides 25% of total energy use in the United States, and 18% of electricity production. It is used for electricity production as well as directly in households and businesses. It is also a very important source of feedstock for fertilizer.

In the last decade, new technology, particularly the commercialization of hydraulic fracturing ('fracking'), has revolutionized natural gas production in the U.S. Fracking allows natural gas trapped in shale rock formations to be released and captured. This has led to natural gas production in areas of the country, such as Pennsylvania and Colorado, where it had previously not been economically feasible. Because of the new shale gas technology production, total natural gas extraction has increased by 15% from the end of 2005 through 2010.

Energy Security

The commercialization of shale gas technology has revolutionized natural gas production in the United States, easing concerns about energy security. Estimates of technically and economically recoverable gas resources have skyrocketed because of the fracking technology.

The U.S. Energy Information Agency (EIA) estimated in 2010 that the United States possesses a total natural gas resource base of 2,552 trillion cubic feet (Tcf) of potential natural gas resources. At current rates of use the United States has reserves for 110 years of natural gas.



Source: EIA, http://www.eia.ogv/naturalgas

Before the boom was apparent – as recently as 2006 – there was pressure from natural gas users to build more liquefied natural gas (LNG) terminals in order to import gas.[27] Now, however, those terminals are increasingly being used to export gas. In just ten years, from 2000 to 2010, U.S. exports of natural gas have increased by over 350%.[28] The natural gas boom in the United States is not only good for American energy security, but it has also helped America's trading partners and allies – especially those in Europe that rely on Russian gas imports – to diversify their fuel sources.

Economic Stability

Natural gas is not as easily transportable as coal or oil. Because it is a gas, it requires significant infrastructure investments in pipelines, liquefied natural gas facilities, or fuel tanks to transport it. This means that there are not unified markets for gas – prices of gas delivered to a facility vary significantly around the world, and indeed in different areas of the country.

This price uncertainty has given utilities some concern about making long-term commitments to using natural gas as a base load power source. Instead, gas power plants have been used as back-up generation for times of peak load.

The fall in gas prices in the U.S. that has accompanied the shale gas boom has begun to stimulate investment in new gas power plants. However, electric utilities are very sensitive about making long-term investments that rely on natural gas – a fuel with a history of surprise price changes – because they are often prevented by state laws and utility commissions from increasing consumer rates when fuel prices increase.

The economic stability of natural gas as an energy source is still an open question, but if prices remain historically low, investors should be expected to test its long-term viability.

Environmental Sustainability

Burning natural gas is more environmentally friendly than any other fossil fuel because it burns cleaner with less pollutants and no mercury. Its greenhouse gas emissions are 117,000 pounds of carbon dioxide per billion btu; 44% lower than coal and 30% lower than oil.[29] This means that if all electricity production currently using coal now were switched to gas, total U.S. greenhouse gas emissions would be about 10% less.

In addition, natural gas power plants are excellent partners to renewable power. Because renewable generation is by its nature variable, it is important to have a ready reserve of reliable power for times when demand exceeds supply. Modern natural gas power plants are able to economically turn on and off, unlike coal or nuclear plants that require long lead times to heat up and cool off. For these reasons, natural gas has been called a 'bridge fuel' to enable greater use of renewable power in the grid.

Although burning natural gas is relatively clean, there is an ongoing debate about how dangerous the mining of gas is for local air and water supplies. Hydraulic fracturing requires that large amounts of water and chemicals be injected deep into the earth at high pressures. There is a justifiable fear, and some evidence, that the chemicals in the fracturing will leach into water supplies.[30] Properly done, the chemicals should not go into the water supply because the fracturing takes place far below the water table.

With more than 460,000 wells operating in the United States, however, it is important that high standards are maintained across the country. Further study, increased transparency, and tight oversight at all stages of the drilling process should be embraced by both regulators and industry.

Fracking has other environmental concerns beyond the possible pollution of water sources. People living in areas with new drilling report higher incidents of asthma. In addition, new drilling requires large amounts of water, increasing water scarcity in areas already under water stress. Finally, new fracking projects in the United Kingdom have been suspended because of concerns about earthquakes.[31]

II. Nuclear Power

Nuclear power is the expression of Einstein's famous equation: $E=MC^2$, or Energy = Mass x Speed of Light, squared. This means there is a tremendous amount of energy locked in the nucleus of every atom. This energy can be released in one of two ways: by splitting the atom (fission) or by fusing two atoms together (fusion).

Humanity first unleashed the full power of the atom with research that led to the building of the first atomic bombs in 1945. Shortly thereafter, in 1952, a thermonuclear hydrogen bomb was tested by the United States – resulting in the first man-made (though uncontrolled) fusion reaction.

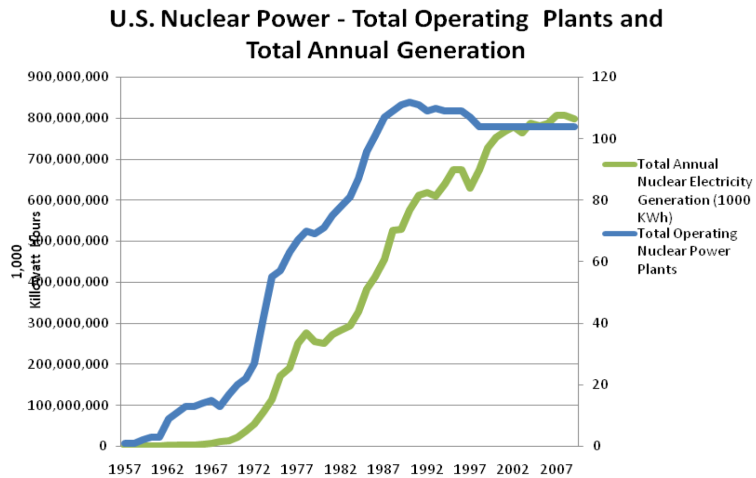
After the world saw the devastation that the atomic bomb could bring, some foresaw that the same power unleashed by nuclear weaponry could be harnessed for peaceful purposes. In this hope, President Eisenhower began the 'Atoms for Peace' program, with a 1953 speech to the United Nations saying, "the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life."[32]

4. Nuclear Fission

American civilian nuclear power began in 1955, when the Atomic Energy Commission asked for proposals from to build nuclear reactors to produce electric power from nuclear fission. By 1960, 3 civilian power reactors were in operation. Twenty years later, by 1980, 87 reactors were in operation around the country.
However, the 1979 accident at Three Mile Island, in which a nuclear reactor's core melted down, and questions about the cost and efficiency of nuclear power, slowed new construction. After 1980, over 100 reactor orders were canceled and fourteen already operational reactors were permanently shut down.

Today, a total of 104 reactors are operational around the country, with a capacity of 101.0 gigawatts. In 2009, nuclear energy provided about 20% of the country's total electricity generation and 9% of total energy.[33]

There is only one nuclear reactor currently under construction in the U.S. Others are awaiting permitting and financing, but forecasts of a 'nuclear renaissance' have not yet come about. One area that could see growth in nuclear reactor construction is small, modular reactors; the Tennessee Valley Authority recently signed a letter of intent to build up to six small reactors. The number of these types of nuclear power plants could increase since financing will be easier to come by and construction will not take as long.

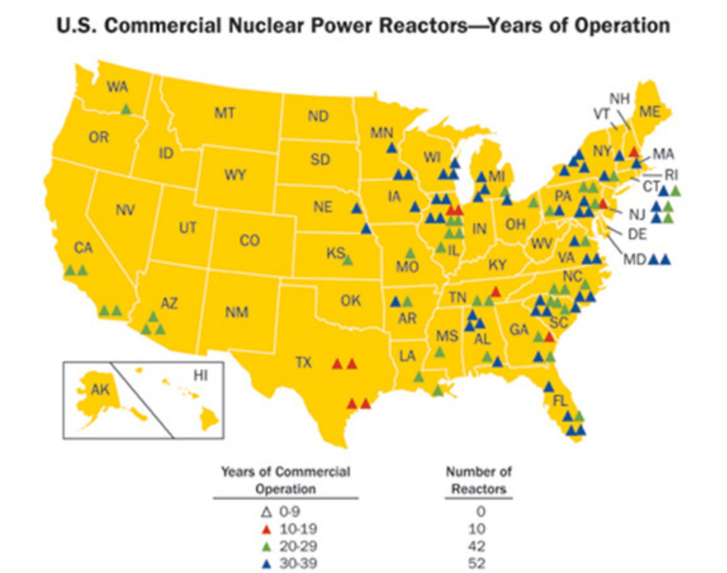


Source: EIA, Nuclear and Uranium, http://www.eia.gov/nuclear/data.fm

Energy Security

From a traditional energy security point of view, increasing use of nuclear fission reactors for electricity would give a strong boost to national energy security: its fuel (uranium) is either available from domestic mines, or from decommissioned nuclear weapons.

However, nuclear power does present more traditional threats to security. Nuclear power plants close to population centers, such as New York's Indian Point reactor, are potential terrorist targets.



Source: U.S. Nuclear Regulatory Commission

Economic Stability

Originally, nuclear power was envisioned as a cheap source of plentiful electricity – most memorably, it was described in 1954 by the head of the Atomic Energy Commission, Lewis Strauss, as "too cheap to meter."[34] Unfortunately, that has not proved to be the case.

Unlike fossil fuel-powered electricity generation, most of the cost for nuclear power is fixed, in up-front infrastructure costs. Once a plant is complete and running, the variable cost of fuel only adds a small amount to the price of electricity generated.

History has shown that the budget for new nuclear reactors, already high, is very often exceeded. An assessment of 75 of America's existing reactors showed predicted costs to have been $45 billion, but the actual costs were $145 billion.[35] The country with the most recent nuclear power construction experience, India, shows that costs of its last 10 reactors have averaged 300% over budget. Once built, however, a noted benefit of nuclear power is that the price of electricity is stable and predictable.

Spent fuel is also a drain on government resources. Under the 1982 Nuclear Waste Policy Act, the U.S. government was to create a permanent storage site for radioactive spent nuclear fuel by February 1998. Thirteen years later, the federal government is no closer to meeting this requirement; as a result, utilities have filed dozens of lawsuits for over $6 billion in claims. Of this, the government has already paid $956 million, and it has spent nearly $170 million simply defending itself. Department of Energy statistics show that new lawsuits and other costs could eventually push the government's legal liability to over $16 billion.[36]

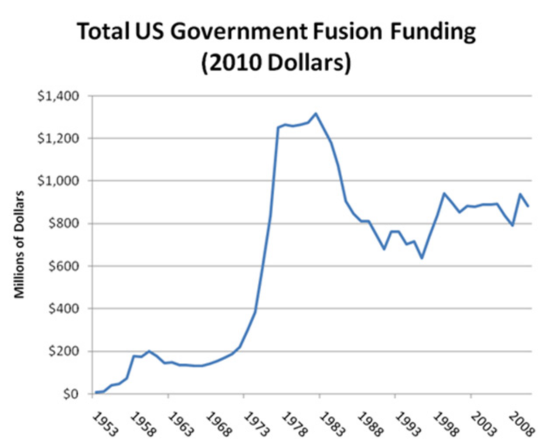
Environmental Sustainability

Nuclear power, both from fission and fusion, does not produce greenhouse gases. For this reason, some environmentalists most worried about climate change have shifted from their traditional opposition to nuclear power. If the United States produced the same percentage of its electricity from nuclear power as France does (77%), it would produce 19% fewer greenhouse gases.

Although there are no polluting emissions from existing (fission) nuclear power, that does not make it completely clean. Spent nuclear fuel, which can consist of radioactive uranium, plutonium, or thorium, presents long-term threats from radiation contamination. After spent nuclear fuel is removed from the reactor, it is placed in temporary water cooling pools within the reactor facility. This was not intended to be permanent, but the government's failure to find a long-term strategy for storing spent nuclear fuel means that most of America's radioactive spent fuel – 63,000 tons of nuclear waste – is stored on-site.[37]

5. Fusion

Fusion has not seen the same success as a source of energy. The basic fuel for fusion is hydrogen, and energy is produced by forcing together the atomic nuclei of deuterium and tritium (two forms of hydrogen) to form helium. A great deal of energy is released by this reaction: one pound of fusion fuel is capable of yielding as much energy as is contained in 10 million pounds of coal.



The first patent related to fusion energy was issued in the United Kingdom in 1946. Since then, there have been a number of significant breakthroughs, including controlled fusion reactions. Up to now, the problems of how to contain the intense heat and pressure need for a sustained fusion reaction have prevented fusion reactions from achieving the point where more energy will be released from the reaction than is being used to initiate and control it.

Recent advances in laser and magnetic technology, however, have raised hopes that fusion could become a new source of electricity over the medium-term. Scientists from the Lawrence Livermore National Laboratory in California, working under the auspices of the National Nuclear Security Administration at the National Ignition Facility (NIF), have predicted that they will be able to achieve a fusion reaction that gets net energy gain – a significant milestone – using advanced lasers for compression and containment by the end of 2012.[38]

Energy Security

Fusion power has the potential to alleviate concerns about energy security. Fuel to power fusion power is available in seawater.

The downside risk on energy security comes from *not* investing in research and development. If other national efforts in other countries, particularly competitor countries like China, are successful in commercializing fusion reactions, then they will sell the technology abroad, at the expense of the U.S.

Importantly, dependence on technology and infrastructure do not raise the same energy security concerns as dependence upon imported fuel does, but they will certainly exert a cost.

Economic Stability

Bringing fusion power to a level that it is commercially viable will require significant research and development spending, estimated at about $35 billion over a 15-year period (or $2.33 billion per year).[39] This is a significant outlay, but for comparison, the cost of the Manhattan project was approximately $22 billion in current dollars over 5 years, and the Apollo program was $98 billion over 14 years.[40]

Once commercialized, power plants are likely to require a high initial construction cost and low operating costs. Fusion has the potential to be a long-term source of energy, but it will require significant and sustained investment in order to meet the engineering and scientific needs required.

Environmental Sustainability

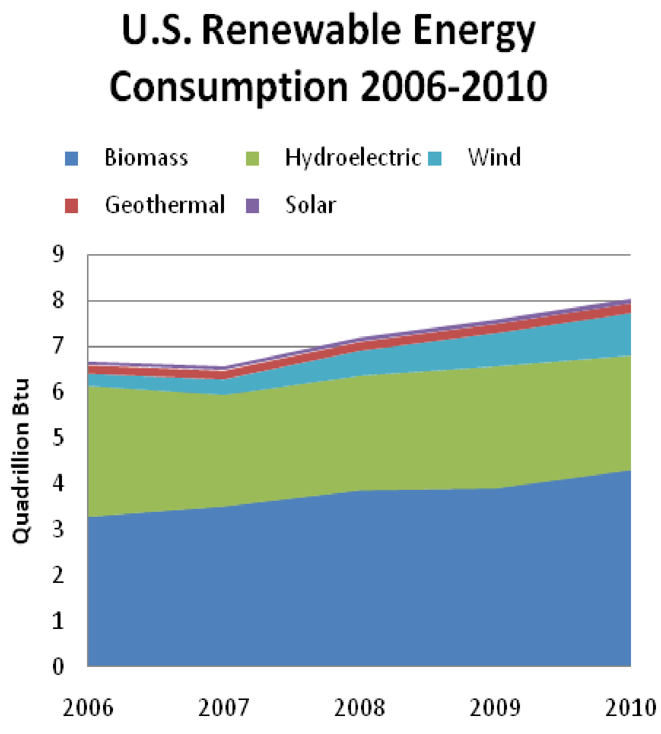
Fusion power does not produce radioactive waste at nearly the same level as fission. In fact, developing fusion may actually help to solve the problem of spent nuclear fuel. Physicists at the University of Texas at Austin have designed a new system that, when fully developed, would use fusion to eliminate most of the waste produced by fission nuclear power plants.

Pairing fission and fusion reactions would also allow the dangerous radiation to be absorbed by fusion reactions, thereby using the harmful radiation from fission reactions to power fusion reactions. In this way, fusion could help the long-term environmental sustainability of existing U.S. nuclear power plants.

III. Renewable Power

Before the widespread adoption of fossil fuels two hundred years ago, renewable sources of power were the only energy sources available. Many towns were built on or near rivers in order to take advantage of the power of running water.

Wind was the prime mode of power for water transportation. Biomass is just a more technical name for burning wood for heat or light. In the 21st century, in an effort to return to an energy system that is more sustainable, limitless, and is less likely to provoke conflict, humanity is returning to its original sources of energy. This time, though, scientists are using the combined technology and innovation of the 21st century in order to better harness these sources. Renewable power includes power generated by water, wind, the sun, plants, or the natural heat of the earth. Together, these five power sources – hydro, wind, solar, biomass, and geothermal – account for 8.2% of total energy generation in the United States, and 10.8% of electricity generation.



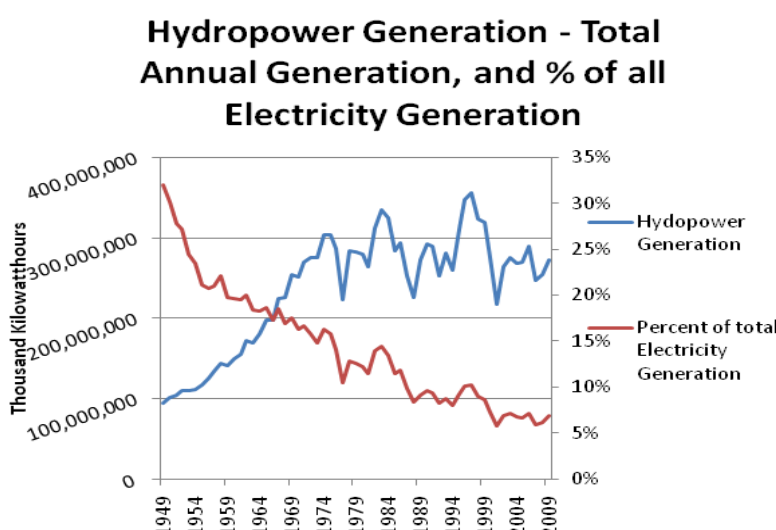
Source: EIA, Renewable Energy Consumption and Electricity Preliminary Statistics 2010, http://www.eia.gov/renewable/annual/preliminary

The different fossil fuel or nuclear sources of energy each present separate challenges or concerns about energy security, economic stability, and environmental sustainability. However, the positives and negative for these three criteria are largely shared across each of the five types of renewable energy source. For that reason, this chapter will briefly give a short overview of each type of renewable power, followed by a discussion of the shared concerns about renewable power for energy security, economic stability, and environmental sustainability.

6. Hydropower

Hydropower is the largest renewable source of energy in the United States. It produces 7% of the country's electricity power – in 1950, it produced 30% of the country's power. The Grand Coulee Dam on the Colombia River in Washington is the largest electricity power plant in the country, capable of generating 6.9 gigawatts of electricity.[41]

However, there is little room for growth. Hydroelectric plants can only operate where rivers provide suitable amounts of potential energy, and most of the best sites have already been developed.



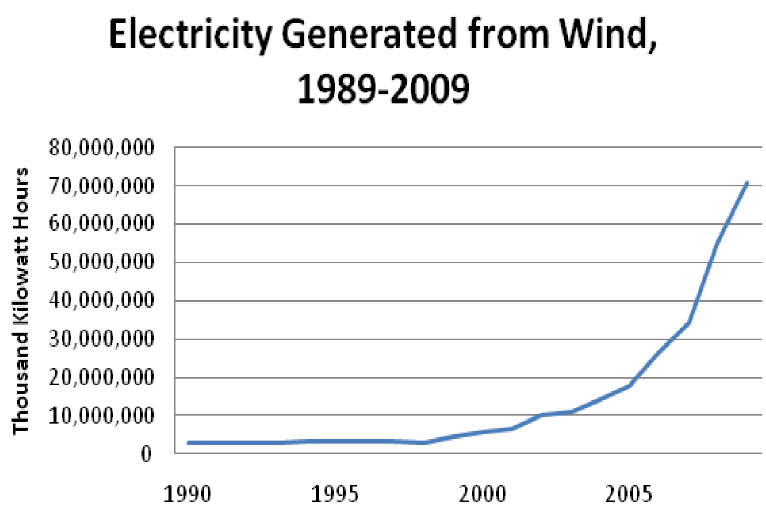
Consequently, conventional hydroelectric generation grew steadily through the 1970s, peaked in 1997, and has been declining for the last decade.

Though there are other forms of hydro generation, like underwater 'run of the river' turbines, their maturity does not approach the level of traditional hydropower, and their development is speculative.

7. Wind

Wind power over the past decade has been the fastest growing source of American energy. For the ten years to 2009, wind had an average annual growth rate of 32%. Today, it accounts for 2% of electricity generation.[42]

Large scale wind farms are being installed across the county. Offshore wind farms are being installed rapidly in some European countries, but in the United States, only two are in the planning process and none have begun construction. Wind farms placed far enough offshore can overcome the often citied opposition to wind that comes from concerns about obstructed views in onshore farms.



8. Solar

Solar power is less utilized than wind in the United States. In 2009, it accounted for only .03% of total energy production, with most of that going to household uses, such as solar heating.[43] Utility-scale electricity generation in the United States from solar cells is still a far-off dream. European governments have been investing more heavily into government policies to promote large-scale solar power.

There are two main ways to produce electricity from the sun. The first is through photovoltaic cells that capture sunlight on silicon and transform it into electricity.

The second is called concentrated solar thermal. In this method, specialized mirrors are used to focus the heat and light of the sun on a central core that is heated. The heat from this core is then used to generate steam, turning a turbine and creating electricity. The benefit of this form of solar thermal power is that the heat of the central core can be maintained so that power can be generated even when the sun goes down.

9. Biomass

Generating energy from biomass is the ability to use plants for fuel. This can be as simple as using waste-wood from sawmills or paper factories in residential heating systems or it can refer to the process of refining corn into ethanol that is then blended into gasoline.

Ethanol is the most important of these fuels in the United States, but other countries have made biodiesel made from oilseeds and palm oil significant parts of their transportation fuels. Given generous subsidies, corn-based ethanol, blended into gasoline, provides about 3.4% of the energy used in transportation.

Advanced forms of biodiesel include proposals to refine fuel from algae.

10. Geothermal

Geothermal power comes from the Earth's natural heat. Residential geothermal systems include simple heat pumps that use the soil's constant temperature to help keep houses warm in the winter and cool in the summer.

Geothermal on a utility-scale is a stable, long-term source of energy, but only in certain areas where the crust of the earth is thin and volcanic or seismic activity is high. The United States currently has the most installed geothermal electricity generation capacity internationally, with approximately 3.1 gigawatts of online capacity.

As of April 2011, geothermal electric power generation is occurring in nine U.S. states: Alaska, California, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah, and Wyoming. The largest producer of geothermal energy is California, with 83% of national generating capacity.[44]

Energy Security

Any form of renewable power presents few concerns about energy security because they do not use a fuel that has to be imported.

Some complain about dependence on imported solar panels or other energy-producing goods from China, but this is not the same as energy security. Unlike dependence on a commodity like oil, importing solar panels – for example – constitute a one-time-only fixed cost. Once the cost is borne, there is very little variable cost for generating renewable energy. The same is true when concerns are raised that importing lithium for advanced batteries will only replace imports from unstable Venezuela or Iraq with imports from unstable Bolivia. This is likewise a false argument, because batteries should be termed as a fixed investment cost, not a variable cost, like fuel. While there are good economic arguments for not being reliant on imports of minerals or renewable energy materials, there are few valid security arguments.

An economy that relies on renewable power for its energy needs will be able to manage its foreign policy independently of how it utilizes energy.

However, given the separation in fuels between electricity generation and transportation, policymakers should not be deluded into thinking that increasing renewable electricity generation will automatically increase energy security. There also needs to be a coherent strategy to use more renewable power in transportation. Only by giving consumers a choice about how to fuel their cars will policymakers be able to break the grip that oil has on transportation.

In the United States, transportation is primarily by automobiles, so any proposal to use more renewable energy in transportation must begin by either electrifying the auto fleet or significantly increasing the availability and use of ethanol and biodiesel.

Economic Stability

Renewable power receives subsidies, and in some cases, very generous ones. Of the five types of renewable power, only conventional hydroelectric is consistently competitive on cost of generation with fossil fuels. However, the demonstrated benefits of generating electricity without using a polluting fuel are a benefit that the government has an interest in promoting.

The problem with the renewable production tax credit and any other subsidies is not that the government is 'picking winners and losers,' but that its choices are inconsistent. For businesses and utilities to make multi-year investments in large-scale renewable energy, they need more certainty than the consistent bipartisan brinksmanship over whether to extend these subsidies for one more year.

In areas of the country with consistent and strong winds, installing new wind turbines is already price competitive with new fossil-fuel generation, without subsidies. However, wind power presents two problems of economic stability: intermittency and grid stability. To overcome these problems will require the electricity grid to modernize from its 19th century roots into a modern 'smart grid.'

With a smart grid, installed energy storage facilities, such as batteries or flywheels, will store electricity for times when it is most needed and computers can direct electricity along long-distance high-voltage lines from areas where the wind is blowing to areas that need electricity.

As mentioned in the 'Fossil Fuels' chapter, this smart grid should be paired with natural gas turbine power plants that can easily increase power to match fluctuating load levels. Hydroelectric power can also be easily stored for times of peak load.

Solar power's economic benefit is its compactness and versatility. It does not require large, expensive solar arrays to generate power. Instead, small units can be installed to offset the costs of electricity. With proper legal regulations (not implemented in all states), consumers can install solar power on their property – likely on their roof – and defray the monthly cost of electricity. At times of low household usage, they can even sell the electricity back to the grid.

Environmental Sustainability

In general, renewable power produces no greenhouse gas emissions. However, that does not mean that they are without environmental controversy.

America's ethanol program, for example, is coming under intense – and justified – scrutiny. There are significant questions about the lifecycle emissions of ethanol. Even though it comes from plants, heavy inputs of fertilizer and use of fossil fuels to produce and transport it mean that the minimal benefit in reduced greenhouse gas emissions may not be worth the subsidies ethanol production receives. Cellulosic ethanol, which is derived from grasses or other sorts of herbaceous plants, is not yet in widespread use. Once it commercially viable, this technology should address the environmental sustainability and the economic concern about using food for fuel.

The main environmental problems with renewable power come from the size of its footprint and its impacts on local wildlife and ecosystems. The Grand Coulee Dam, for example, flooded a 125 square mile area, displacing thousands and permanently ending the annual salmon run up the Colombia River.

Large solar power plants planned for the California deserts are currently coming up against opposition from environmentalists who want to protect endangered wildlife from human encroachment.

The environmental opposition to the sites of some renewable power plants comes down to prioritization. Is the health of local ecosystems more important than promoting new technologies that could prevent the many dangers associated with climate change?

Conclusions

The challenges facing America on how to produce and use the energy it needs for every aspect of modern life are not new. The last time the United States faced a series of choices about its energy policy was in the energy crises of the 1970s, which were traumatic to the United States, with oil price spikes, shortages of gasoline, inflation, and nuclear scares. Decisions about energy production and use made in response to these crises had far-reaching consequences for America's energy infrastructure, its economy, and its foreign policy.

Today, America is facing some of the same challenges – as concerns about energy security are once again at the top of the agenda. However, the new complication dealing with a changing climate means that greenhouse gas emissions are an added concern.

None of the challenges are insurmountable, but they do require that people – in government and in the private sector – make choices and priorities. Simply retaining the status quo provides intolerably high levels of risk to energy security, economic stability, and environmental sustainability.

The United States cannot afford a foreign policy that continues to be worried about distant oil markets. It cannot allow the dollar to continue to be debased by sending $680 billion per year to foreign countries simply to be allowed to drive. It is dangerous to allow greenhouse gas emissions to grow unchecked.

To meet these challenges will require policymakers to make some decisions and set some priorities that will not always be popular. But, in the long-term, they are in the best interests of the country.

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Building a New American Arsenal

The American Security Project (ASP) is a bipartisan initiative to educate the American public about the changing nature of national security in the 21st century.

Gone are the days when a nation's strength could be measured by bombers and battleships. Security in this new era requires a New American Arsenal harnessing all of America's strengths: the force of our diplomacy; the might of our military; the vigor of our economy; and the power of our ideals.

We believe that America must lead other nations in the pursuit of our common goals and shared security. We must confront international challenges with all the tools at our disposal. We must address emerging problems before they become security crises. And to do this, we must forge a new bipartisan consensus at home.

ASP brings together prominent American leaders, current and former members of Congress, retired military officers, and former government officials. Staff direct research on a broad range of issues and engages and empowers the American public by taking its findings directly to them.

We live in a time when the threats to our security are as complex and diverse as terrorism, the spread of weapons of mass destruction, climate change, failed and failing states, disease, and pandemics. The same-old solutions and partisan bickering won't do. America needs an honest dialogue about security that is as robust as it is realistic.

ASP exists to promote that dialogue, to forge consensus, and to spur constructive action so that America meets the challenges to its security while seizing the opportunities the new century offers.

ASP

American Security Project

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