The High Cost of Nuclear Power

Why America Should Choose a Clean Energy Future Over New Nuclear Reactors

Georgia PIRG Education Fund

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Executive Summary

Nuclear power is among the most costly approaches to solving America's energy problems. Per dollar of investment, clean energy solutions – such as energy efficiency and renewable resources – deliver far more energy than nuclear power.

This fact has important implications for America's energy policy. By directing resources toward the most cost-effective solutions, we can make greater progress toward a secure, reliable and safe supply of electricity to power America's economy.

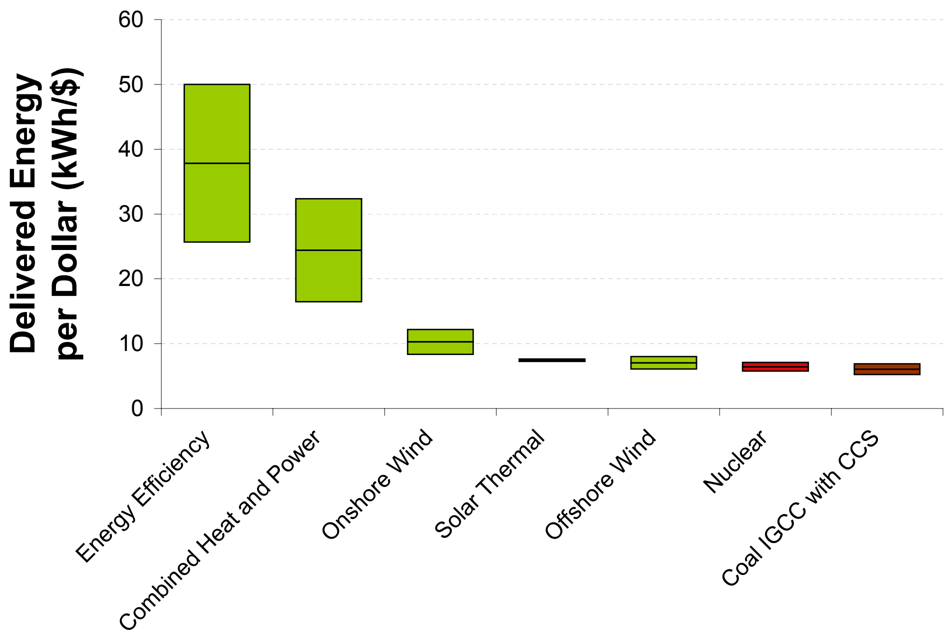
Dollar for dollar, a clean energy portfolio can deliver more energy than nuclear power. Per dollar of investment:

- Energy efficiency measures can deliver greater than five times more electricity than nuclear power.
- Combined heat and power (which generates both useful heat and electricity for a factory, a school campus or an office building) can generate nearly four times more energy than nuclear power.
- Wind farms can produce as much as 100 percent more electricity than nuclear power.
- A solar thermal power plant in the southwestern U.S. – capable of storing heat to generate electricity even when the sun isn't shining – can deliver as much as one-third more energy than a nuclear reactor. (See Figure ES-1.)

Since 2005, cost estimates for building a new nuclear reactor have more than tripled.

- Estimated costs for nuclear reactors have risen faster than for other types of generation technologies. The nuclear industry in particular faces a shortage of qualified and experienced engineers, manufacturers, and construction workers. For example, only one metal foundry in the world today is capable of forging ultra-heavy reactor vessels – and it is located in Japan.

Figure ES-1: Electricity Delivered to the Consumer per Dollar of Investment (Levelized) – A Comparison of Select Low-Carbon Energy Technologies



This figure presents the amount of electricity delivered to the consumer per dollar of investment in different energy technologies, with the investment per unit of energy production "levelized" (or averaged) over the lifetime of the technology to enable meaningful comparison. Each bar represents the range between high and low productivity estimates, accounting for differences in the technology used, variability in the quality of the natural resource, and the precision of cost estimates. Values for energy efficiency, combined heat and power, nuclear and coal are not specific to any particular location. Wind energy estimates represent the average resource for the U.S. as a whole. Estimates for solar thermal represent typical resources in the southwestern United States. (IGCC with CCS stands for integrated gasification combined cycle with carbon capture and sequestration, a potential method of producing effectively low carbon electricity from coal.) *See page 27 for more details.*

- In June 2008, staff at the Federal Energy Regulatory Commission estimated that building a new 1,000 megawatt (MW) reactor could cost up to $7.5 billion. Moody's Investor Service estimates that at that price, reactor owners would have to sell electricity at an average of 15 cents per kilowatt-hour (kWh) over the life of the plant in order to earn an adequate profit.

Building all currently planned nuclear power plants could cost $300 billion.

- As of February 2009, power companies have announced plans for 30 new nuclear reactors. Altogether, building these reactors could cost as much as $300 billion.
- To put this amount in perspective, $300 billion is more than double the estimated cost to repair all the roadway bridges in the United States.

Utilities planning to build new nuclear plants are transferring risks onto taxpayers and consumers – especially in southern states.

- In 2005, Congress created a series of taxpayer-financed subsidies to support the construction of new nuclear reactors, including loan guarantees, extended liability insurance, and a tax credit for every kilowatt-hour of nuclear electricity generated. Altogether, the subsidies are valued at as much as 60 to 90 percent of the levelized cost of power from a new nuclear reactor – reaching as high as $13 billion for a single reactor.
- Many regulated utilities working to build new nuclear capacity are charging customers up-front to finance reactor construction – with no guarantee of final cost, or even a guarantee that the plant will ever deliver electricity at all. For example, Florida regulators are allowing Progress Energy to start billing customers in 2009 for the planning, development and construction of two nuclear power plants that will not begin delivering electricity until 2016 at the earliest. As construction proceeds, residential customers could end up paying as much as $25 more a month to finance the nuclear reactors.
- Other utilities planning advance charges include Georgia Power, South Carolina Electric & Gas, Santee Cooper in South Carolina, and Ameren in Missouri.

Photo: NREL

Investing in clean energy solutions rather than a fleet of new nuclear power plants would yield greater benefits for America.

- The United States has vast clean energy resources. The American Council for an Energy-Efficient Economy – composed of some of the nation's leading experts on energy efficiency – estimates that the United States could cost-effectively reduce its overall energy consumption by 25 to 30 percent or more over the next 20 to 25 years. Progress at this level would ensure that America uses less energy several decades from now than we do today, even as our economy grows. At the same time, America's entire electricity needs could be met by the wind blowing across the Great Plains or the sunlight falling on a 100 mile square patch of the desert Southwest, or a tiny fraction of the natural heat just beneath the surface of the earth anywhere across the country.
- Directing $300 billion into energy efficiency could eliminate growth in America's electricity consumption through 2030 and save consumers more than $600 billion. Energy savings in 2030 would be equivalent to the output of more than 80 nuclear

reactors. Alternatively, $300 billion could buy enough wind turbines to supply on the order of 10 percent of America's projected electricity needs in 2030 – equivalent to the output of more than 40 nuclear reactors.

- Research by the European Renewable Energy Council shows that clean energy resources in the United States could deliver substantial pollution reductions at half the cost and with twice the job creation that could be achieved with nuclear power and fossil energy sources.

Clean energy solutions are able to meet demand for electricity in small, modular amounts – posing far less financial risk than nuclear power plants.

- The 2008 meltdown of the U.S. financial system and the ensuing economic crisis could retard growth in demand for electricity. As a result, the demand a nuclear power plant is meant to serve may not materialize. And since nuclear power plants are large and inflexible, this possibility poses a serious financial risk for any utility considering a new nuclear power plant, and its customers. Construction of a nuclear power plant cannot be halted halfway to get half of the power output – it's all or nothing.
- In contrast, clean energy solutions are typically modular – they can be assembled into units tailored precisely to an evolving need for electricity.

America should reform its energy policy to prioritize clean energy solutions – technologies that deliver safe, reliable and secure electricity supplies at a reasonable cost.

- State leaders should **protect citizens from unnecessary risks** by requiring any company proposing to build a new nuclear reactor to demonstrate that nuclear would be more cost-effective than other ways to meet electricity demand, including energy efficiency, before allowing construction to proceed.
- Federal and state leaders should ensure that energy companies and their shareholders shoulder all of the financial risk of any new nuclear reactor project, not ratepayers or taxpayers. In particular, regulators should not allow utilities to levy advance charges on consumers in order to finance the construction of a new reactor. Congress should also repeal the Price Anderson act, under which taxpayers shoulder the lion's share of responsibility for any major nuclear accident.
- America should shift current federal subsidies away from nuclear and fossil fuel energy, creating billions annually for research, development and deployment of more effective energy efficiency and renewable energy technologies.
- America should **speed the introduction of clean energy technologies** by enacting a national energy efficiency resource standard to require, at minimum, that all new demand for electricity be met with energy efficiency measures; and a national renewable electricity standard to ensure that 25 percent of America's electricity supply comes from renewable sources by 2025. States should also create or expand analogous policies at the state level.

Introduction

No power company has successfully ordered a nuclear reactor in the United States since 1973. Despite promises of power that would be "too cheap to meter," the last generation of nuclear reactors ran aground on skyrocketing construction costs. Of 75 nuclear reactors completed between 1966 and 1986, the average reactor cost more than triple its original construction budget.[1] Later-built reactors came in as much as 1,200 percent over-budget.[2] In 1985, *Forbes* magazine wrote that "the failure of the U.S. nuclear power program ranks as the largest managerial disaster in business history, a disaster on a monumental scale."[3]

Electricity customers ended up paying the price. Only one-half of the reactors proposed were ever built, and ratepayers often had to bear the costs of abandoned projects. Where reactor projects were completed, rates often increased. Finally, during the restructuring of the electricity industry in the 1990s, ratepayers were saddled with billions in "stranded costs" from failed investments in nuclear power, saving nuclear power plant owners (and their shareholders) from huge losses.[4]

For decades, the nuclear industry languished.

However, today, the situation seems different. Concerns over global warming are driving utilities to seek low-emission sources of electricity and reduce dependence on coal. And utilities are working to diversify fuel sources in the face of uncertainty over the long-term availability of natural gas supplies.

As a result, the nuclear industry has regained a foothold toward a long hoped-for revival. As recently as 2002 the French government called nuclear power "a monster without a future."[5] Yet now a French-supported firm is building three new nuclear power plants in Finland, China and France.[6] At a 2008 conference in London, Lady Barbara Judge, chairwoman of the British Atomic Energy Authority, told attendees that "[a]tomic was a dirty word but now it's certainly a sexy one."[7]

In the United States, Congress has offered multi-billion dollar subsidies

> "The failure of the U.S. nuclear power program ranks as the largest managerial disaster in business history, a disaster on a monumental scale. The utility industry has already invested $125 billion in nuclear power, with an additional $140 billion to come before the decade is out, and only the blind, or the biased, can now think that the money has been well spent. It is a defeat for the U.S. consumer and for the competitiveness of U.S. industry, for the utilities that undertook the program and for the private enterprise system that made it possible."
>
> –"Nuclear Follies," a February 11, 1985 cover story in *Forbes Magazine*

to companies that launch a new era of nuclear power plant construction. Billions more are potentially on the table. In response, more than 20 companies have announced plans to build as many as 34 new nuclear reactors over the coming decades.

Nuclear companies promise that a new generation of reactors could meet America's electricity needs, increase our energy independence, reduce our dependence on fossil fuels, minimize our vulnerability to price spikes and lessen our contribution to global warming. Moreover, nuclear companies pledge that they have learned from their mistakes, and that today's reactors will be more cost-effective investments.

In this report, we take a closer look at the costs likely to accompany any new generation of nuclear reactors. We compare nuclear with other energy technologies capable of reducing our dependence on fossil fuels and contribution to global warming.

Before rushing headlong into a new nuclear age, America should carefully evaluate all of the available options and choose those best able to deliver a safe, secure and reliable supply of electricity for the most reasonable cost. Particularly in these troubled financial times, government has a responsibility to make sure that our energy dollars are invested wisely.

The High Cost of Nuclear Power

In 2003, a group of experts at the Massachusetts Institute of Technology and Harvard evaluated the future of nuclear power. They concluded that "today, nuclear power is not an economically competitive choice."[8] Without new policies offering financial support to the nuclear industry, the MIT researchers predicted that "nuclear power faces stagnation and decline."[9]

Since that time, the estimated cost of a new nuclear power plant has escalated dramatically. Despite billions in government subsidies over the decades, nuclear power remains among the most costly approaches to solving America's energy problems.

The Estimated Cost of Building a Nuclear Power Plant Has Skyrocketed

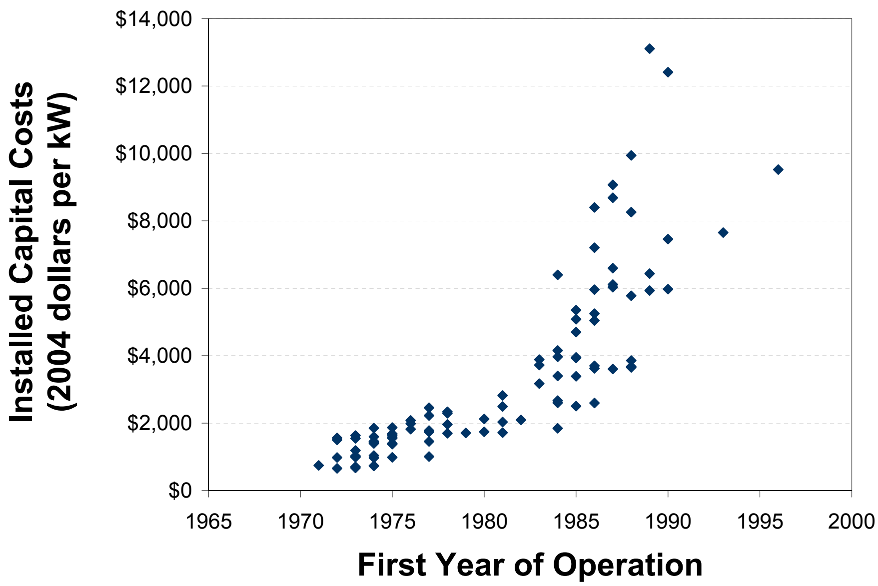
In the early 2000s, nuclear industry executives estimated that construction costs for building a new nuclear reactor could approach $1,500 per kilowatt (kW) of power generating capacity, plus finance costs.[10] At that price, they maintained that nuclear power would be competitive with most competing power generation technologies, including coal and natural gas.

However, that estimate now appears wildly optimistic. During the last wave of nuclear power plant construction in the United States, capital costs far exceeded this benchmark. And since 2005, the anticipated cost of a new nuclear power plant has more than tripled.

Costs Escalated Rapidly During the Last Wave of Reactor Construction

Economists commonly expect that new products and technologies become cheaper over time, as companies gain experience and develop economies of scale.

Figure 1: Actual Capital Costs of Completed U.S. Nuclear Reactors (in 2004 Dollars)[11]



However, in the case of the last generation of nuclear power in the United States, the opposite proved to be true. The first nuclear reactors ever built were among the least expensive, while costs spiraled wildly out of control in the final decades of reactor construction. (See Figure 1.) For plants beginning operation in the late 1970s and onward, inflation-adjusted capital costs escalated from just under $2,000 per kW to more than $10,000 per kW (in 2004 dollars).

In 1973, the beginning of the Arab oil embargo, the United States entered a period of economic turbulence that increased the cost of power plant construction, while simultaneously reducing demand for power.[12] As power companies began to realize that predictions for future electricity demand were greatly overestimated, and as construction costs escalated, executives canceled more than 100 reactor projects, some in the middle of construction.[13]

Complicating the situation, in 1979, a reactor at Three Mile Island in Pennsylvania suffered a partial meltdown, turning the tide of public opinion against nuclear power. Construction times for reactors built after 1979 extended up to 10 to 15 years and beyond, greatly increasing finance costs for reactor owners. And finally, many reactor projects suffered from quality control problems during construction.[14]

Today, the nuclear industry promises that new, standardized designs and technological advances will enable reactor construction to proceed without the delays and cost-overruns of the past, while maintaining an adequate margin of safety.[15] However, recent cost escalation, construction delays, and the fallout from the collapse of the U.S. financial system suggest that a new generation of nuclear reactors would suffer from the same problems as the last.

The Anticipated Cost for Building a New Nuclear Reactor Has More than Tripled

In June 2007, a group of nuclear experts assembled by the Keystone Center published a re-evaluation of the cost of building a new reactor, taking into account the effects of rising prices for important commodities like steel and concrete.[16] The group found that the probable cost of a new reactor had risen to $3,600 to $4,000 per kW (in 2007 dollars).[17]

If anything, the Keystone estimate was too low. That same month, UniStar Nuclear submitted a proposal to build a new reactor at Calvert Cliffs in Maryland, pegging the cost at about $4,300 per kW.[18]

Moody's Investment Service, a credit rating agency advising Wall Street investors, felt that industry cost estimates were still falling short. In October 2007, Moody's estimated that a new reactor could actually cost as much as $6,000 per kW on the high end.[19]

By early 2008, power companies were developing cost estimates that exceeded even the most pessimistic limit of Moody's projections. For example:

- In February 2008, FPL Group projected that an expanded reactor system at Turkey Point in Florida could cost about $4,200 to $6,100 per kW.[20]
- In March 2008, Progress Energy estimated that two nuclear reactors in Levy County, Florida would cost roughly $6,300 per kW – not including the cost of upgraded transmission lines.[21]

By May 2008, costs showed no sign of decreasing. *The Wall Street Journal* reported:

> "Estimates released in recent weeks by experienced nuclear operators – NRG Energy Inc., Progress Energy Inc., Exelon Corp., Southern Co. and FPL Group Inc. – "have blown by our highest estimate" of costs computed just eight months ago, said Jim Hempstead, a senior credit officer at Moody's Investors Service credit-rating agency in New York."[22]

In June 2008, staff at the Federal Energy Regulatory commission estimated that building a new 1,000 megawatt (MW) reactor could cost up to $7.5 billion.[23] At that cost, analysts at Moody's calculate that reactor owners would have to sell power in the market at 15 cents per kWh (without transmission and distribution costs) in order to achieve a 10 percent return on the investment.[24]

Hopes that a new generation of nuclear reactors could avoid the high construction costs that plagued the industry in the past appear to be overly optimistic. A reactor built at $6,000 to $7,500 per kW would be more expensive than 85 to 90 percent of the reactors built to date in the United States.[25]

Comparing Nuclear Cost Estimates

Cost estimates from different sources are notoriously difficult to compare directly. Estimates often rely on different assumptions (such as the duration of construction) and they can exclude important costs (such as finance). The figures cited on this page are not directly comparable – but they are meant to give a sense of how cost estimates have evolved in recent years. For a direct comparison of the cost of nuclear-generated electricity with other sources of power, see page 26.

Nuclear Costs Have Risen Faster than Other Generation Technologies

While anticipated costs for building power plants of all stripes are rising, nuclear costs have risen faster than other generation technologies.

According to Cambridge Energy Research Associates (CERA), a firm that tracks capital costs for building new power plants, the cost of building a new power plant fueled by coal, gas, or wind climbed by nearly 80 percent from 2000 to 2007.[26] However, the anticipated cost of building a new nuclear reactor rose more than twice as fast as these competing technologies, expanding by 185 percent over this same period.[27]

All power plants are affected to some degree by changes in prices for key commodities like steel, concrete and copper, and by factors such as currency exchange rates. However, commodity prices make up only about 5 percent of the total cost of a nuclear reactor.[28]

Much more significantly, the nuclear industry faces an acute shortage of workers qualified to build nuclear facilities and limited manufacturing capacity for specialized nuclear components.[29] No American company has ordered a new nuclear power plant since 1973. As a result, domestic manufacturing capability for nuclear reactor parts has withered and trained personnel are scarce.[30] While the United States had 900 certified nuclear component suppliers two decades ago, today there are fewer than 200.[31] In addition, only two metal foundries in the world today are capable of forging heavy nuclear reactor vessels – and they are located in Japan and France.[32] Only the facility in Japan has the capability to forge vessels larger than 500 tons.[33] And the nuclear industry must compete with the petrochemical industry for access to these facilities.[34]

In October 2008, AREVA (a company controlled by the French government) announced that it will be opening a manufacturing facility for large reactor components in Virginia, scheduled to open in 2011.[35] Companies are likely to respond to increased demand for reactor components by opening new facilities such as this, which will moderate price increases to some extent. However, the massive nature of nuclear facilities will limit the extent to which economies of scale can be realized, especially compared to smaller and more modular technologies such as energy efficient appliances, wind turbines, or cogeneration units.

Delays and Cost Overruns Appear Likely

AREVA, a French government-owned nuclear developer working in partnership with Constellation Energy to bring its reactor technology to the United States, provides an example of what could occur should a power company choose to build a new nuclear power plant. AREVA is currently building a reactor in Finland.[37] The reactor is the first of its kind in the world, incorporating advanced design features the industry had hoped would keep construction costs in check.

However, the project has suffered from delays and cost overruns, much like past nuclear reactor construction. The project is now three years behind schedule.[38]

> "Nobody has ever over-estimated the construction cost of a nuclear power plant at the pre-construction stage."
>
> – Dr. Paul Joskow, Massachusetts Institute of Technology, May 19, 2006[36]

AREVA started construction on the project before the design was finalized and approved by regulators. Moreover, construction has included a variety of costly mistakes. Welds for the reactor's steel liner were flawed, and had to be redone. Water coolant pipes were revealed as unusable. And concrete poured in the foundation was suspect, with too much moisture content to meet safety requirements.[39] Analysts estimated in September 2007 that the delays added $2.2 billion to the cost of the plant – 50 percent above original estimates.[40] When *Washington Monthly* editor Mariah Blake visited the site in November 2008, someone had scrawled the word "Titanic" on the steel interior of the containment building.[41]

Delays continue to mount and the final price tag is unknown, but it is likely to exceed $6 billion.[42] AREVA and the Finnish utility TVO are locked in a dispute over who will be responsible for the cost overruns.[43] Meanwhile, a coalition of Finnish industries estimates that the delays will indirectly cost electricity users $4 billion in higher power bills.[44]

The Finnish reactor is not the only nuclear project behind schedule. A second AREVA reactor being built in France is now reportedly nine months behind schedule, even though construction began barely a year ago.[45] Project coordinators now admit that the project is already 20 percent over budget.[46]

A new generation of nuclear reactors in the United States would likely face similar difficulties. Despite the fact that national expertise in manufacturing and building nuclear plants has withered in the last few decades and component supply bottlenecks are developing, power companies are counting on quick and efficient construction. Recent reactor proposals estimate construction durations of five to six years – faster than 80 to 90 percent of all reactors completed during the last wave of reactor construction in the United States.[47]

According to Jim Harding, a nuclear energy expert who participated in the Keystone study, even though many of these proposals put forward relatively high construction cost estimates, "none could be called 'worst case'."[48]

Further complicating matters are possible delays at the Nuclear Regulatory Commission (NRC). Facing a large volume of reactor applications – coupled with a lack of qualified staff – the NRC is outsourcing application reviews to third-party contractors.[49] Moreover, the NRC is reviewing and certifying five new reactor designs – with probable delays caused by ongoing design modifications and revisions.

The Impact of the 2008 Financial Crisis

The financial crisis that developed in September 2008 has appeared to have little effect on price escalation for new nuclear plants, but it has created new obstacles and risks.

Despite depressed economic conditions, investment analysts at Standard & Poor's found no fundamental changes in the factors driving nuclear costs upward. In October 2008, the credit rating agency issued a report entitled, "Construction Costs to Soar for New U.S. Nuclear Power Plants."[50] Soon after, Duke Energy doubled the expected construction costs of its proposed Lee Nuclear Station, reaching about $6,300 per kW.[51] That same month, *Platts Nucleonics Week* interviewed experts and industry officials, describing the anticipated impact of the financial crisis on global nuclear revival as "moderate," foreseeing possible benefits in easing the supply chain or credit crunch due to an economic slowdown.[52]

However, the financial crisis has contributed to a slackening in demand for electricity and higher costs for capital. If these conditions persist, utilities could find investments in new nuclear power plants more difficult to justify or to finance. The situation is eerily reminiscent of the conditions that sank the last wave of U.S. nuclear power plant construction.

Drop in Electricity Use Increases the Risk that New Nuclear Plants Will Not Be Needed

In 2008, utility companies noticed an exceptional decline in electricity consumption.[54] While the economic crisis likely contributed to the drop in energy demand, utility executives have also expressed concern that the trend marks a deeper shift in consumption patterns.[55]

If the trend holds, utilities run the risk of building too much generating capacity, burdening customers and shareholders with unnecessary costs. Michael Morris, the chief executive at American Electric Power, sounded a cautionary note. Quoted in the *Wall Street Journal*, he warned, "The message is, be cautious about what you build, because you may not have the demand [to justify the expense]."[56]

Compounding the problem are the high cost estimates for new nuclear reactors. Some estimates of the cost of power from a new nuclear reactor range as high as 25 to 30 cents per kWh – triple electricity rates in most parts of the country.[57] Adding power at even half this price to a service territory could increase the cost that consumers pay for electricity, motivating additional efforts to conserve and dampening the power demand the plant was built to serve.

This exact situation contributed to the failure of the last wave of nuclear power plant construction in the United States. Dozens of reactors were cancelled, and billions of dollars in unnecessary investment were lost.

> "Even before the scale of the impact of the financial crisis began to be appreciated the cracks in the nuclear renaissance were becoming clear. The [reactor] designs were unproven; costs were escalating sharply; obtaining finance was problematic; and [there were] skills shortages and component supply bottle-necks. The financial crisis has done nothing to lessen these concerns."
>
> –Steven Thomas, University of Greenwich Business School, February 11, 2009[53]

Tight Credit Markets Could Increase the Cost of Finance

The *Wall Street Journal* reports that power companies have been "hobbled by the financial crisis," impairing their ability to finance any new projects, much less huge new nuclear reactors.[58] "Interest costs have increased to two to four times what they were a couple of years ago, greatly inflating the ultimate price tag for the big, lengthy projects."[59]

In addition, power companies operating in deregulated electricity markets face the escalated risk of a credit downgrade. For example, after doubts arose about its ability to cover its debts during the financial meltdown, Constellation Energy Group suffered a 75 percent drop in its stock value and reached the verge of bankruptcy. The company had expanded its business into energy trading, much like a Wall Street investment bank. The company had underestimated the amount of collateral it required to cover trade agreements in the event of a credit downgrade – and when such a downgrade happened, the company was forced to auction itself off for a fraction of its previous value, or go bankrupt.[60] According to *Baltimore Sun* financial columnist Jay Hancock, Constellation created its own problems by "betting on energy trends with buckets of borrowed money, then by misstating what would happen if the credit ratings it needed to borrow that money were ever downgraded."[61]

This situation highlights the extreme risk that utilities operating in deregulated electricity markets would take on by borrowing the billions necessary to build a new nuclear power plant. By taking on more debt, companies increase the odds of a credit downgrade, which would require a company to raise potentially billions more to cover expenses unrelated to the nuclear plant – leaving shareholders, and potentially ratepayers, vulnerable to the consequences.

To manage the risk, nuclear power companies are seeking partners to share the burdens of reactor construction, while hoping that the credit situation will loosen in the next few years, before full financing packages need to be assembled.[62]

Despite the financial meltdown, credit rating agencies continue to express optimism about the utility sector overall.[63]

> Electricity customers "spent tens of billions of dollars saving nuclear power plant owners from large losses, even bankruptcy" during the 1990s. "The loan guarantees [offered under the 2005 Energy Policy Act] arrange the next multibillion-dollar rescue before the fact and charge it to taxpayers instead of customers."
>
> – Peter Bradford, former Nuclear Regulatory Commissioner, quoted in the *Washington Post*, 18 December 2007.[64]

Part of the optimism stems from the hope or expectation that utilities will benefit from federal loan guarantees or will be able to collect construction costs from customers before building begins – thus transferring the risk onto taxpayers and ratepayers.

Nuclear Power Companies are Counting on Consumers and Taxpayers to Bear the Risks of Reactor Construction

Jeffrey Immelt, CEO of General Electric, told an audience at Dartmouth College in New Hampshire that the future of nuclear generation will be limited without government intervention, because of high construction and insurance costs.[65]

In recognition of this fact, nuclear power companies have pursued a variety of subsidies and policy changes that shift risks that private investors are unwilling to shoulder onto taxpayers and customers instead – all while limiting public involvement in the regulatory process.

Shifting Risk onto Taxpayers

From the beginning, U.S. taxpayers have been instrumental in financing the deployment of nuclear technology. From 1950 to 1999, the federal government subsidized nuclear power to the tune of $145 billion.[67]

Despite this massive level of historical support, the nuclear industry still requires assistance in order to have a chance at competing in the electricity market. In other words, although nuclear technology is already mature, it is too uneconomic to secure private investment.

Instead, the nuclear industry has turned to Congress to put up more money. In 2005, Congress passed an energy bill containing numerous additional subsidies for a new generation of nuclear reactors, since expanded in subsequent legislation. Some of the largest subsidies are:[68]

- Unlimited taxpayer-backed loan guarantees, covering up to 80 percent of the cost of a nuclear plant.[69]
- An extension of the Price-Anderson Act, which limits nuclear industry liability in the case of a major accident.
- $5.7 billion in operating subsidies, such as a 1.8 cent tax credit for each kilowatt-hour of electricity produced from a new reactor during its first eight years of operation.
- $2 billion to insure companies against any costs caused by delays in licensing the first six new reactors. Covered delays include those that result from action by the Nuclear Regulatory Commission or litigation, even if the delay helps protect public safety.
- $1.3 billion for decommissioning old plants.
- $2.9 billion for research and development.
- $2 billion for a uranium enrichment venture.

The value of all the subsidies currently on offer to the nuclear industry is substantial – reaching as high as $13 billion for the single proposed reactor at Calvert Cliffs in Maryland, for example.[70] Altogether, the subsidies are valued at as much as 60 to 90 percent of the levelized cost of power from a new nuclear reactor.[71]

Loan Guarantees

The loan guarantees allow companies wishing to build a nuclear power plant to obtain highly favorable financing. The loans can only come from the U.S. Treasury, via the Federal Financing Bank.

> "Without loan guarantees, we will not build nuclear plants."
>
> – Michael J. Wallace, Executive Vice President of Constellation Energy, quoted in the *New York Times* on July 31, 2007.[66]

If the company can't pay the loan back for any reason, taxpayers would cover the loss.

Nuclear Energy Institute President Frank Bowman has defended the loan guarantees, saying: "Loan guarantees will not involve the expenditure of any federal tax dollars when the clean energy projects are successfully completed."[72]

However, the risk that nuclear reactors will not be successfully completed is substantial. For example, when evaluating the Energy Policy Act of 2003, which proposed guaranteeing half the financing for new nuclear reactors, the Congressional Budget Office (CBO) wrote: "CBO considers the risk of default on such a loan guarantee to be very high – well above 50 percent. The key factor accounting for this risk is that we expect that the plant would be uneconomic to operate because of its high construction costs, relative to other electricity generation sources."[73]

Mary Anne Sullivan, former general counsel for the U.S. Department of Energy, has estimated that three-fourths of past loan guarantees for similar projects had resulted in default.[74] For example, 10 of 14 large projects with loan guarantees offered during the 1970s ultimately failed, including a useless synfuel plant that cost taxpayers $13 billion.[75]

The ultimate measure of the risk of default may be the transfer of "stranded costs" from nuclear utilities to customers in the 1990s during the restructuring of electricity markets. Moody's estimated that the value of the customer rescue was "between $50 billion and $300 billion" and shielded several companies from bankruptcy.[76]

The nuclear industry has argued that the loan guarantees will be necessary just to get the first few plants off the ground. However, as of November 2008, nuclear companies have submitted 19 applications for $122 billion in loan guarantees, far in excess of the $18.5 billion that Congress has thus far appropriated.[77]

Nuclear industry lobbying in Congress points toward an agenda to obtain loan guarantees and other subsidies for every new nuclear plant. In 2007, lobbyists for the industry asked lawmakers for as much as $50 billion in loan guarantees over two years in order to finance a nuclear expansion.[78]

The proposed *New Energy Reform Act of 2008* would have expanded the loan guarantee program substantially by allowing the Department of Energy to issue unlimited loan guarantees without annual oversight by Congress. Physicians for Social Responsibility estimates that the expanded program, applied to 34 possible new reactors, would total $170 to $320 billion. At a 50 percent default rate, the ultimate cost to taxpayers would equal $84 to $160 billion.[79]

In addition, nuclear advocates are pressing Congress to fund the construction of a nuclear fuel reprocessing facility, to offer greater construction and operating risk insurance, to increase resources for the Nuclear Regulatory Commission and speed regulatory proceedings, to offer additional tax credits, and to spur the U.S. manufacturing of nuclear reactor components.[80]

"You can't expect the consumer to take on all the risk and pay for it in higher bills."

– David Springe, President of the National Association of State Utility Consumer Advocates[83]

Accident Liability Cap

The 2005 Energy Policy Act also renewed a long-standing limit on liability for nuclear power plant owners, protecting the industry from losses in the event of a major accident. This liability cap, sometimes referred to as the Price-Anderson Act, ensures that taxpayers assume the risk of a major nuclear accident.

Under the Price-Anderson Act, the nuclear industry is liable for only the first $10 billion in inflation-adjusted damages in the event of a catastrophe.[81] By one estimate, power plant operators would be responsible for only 2 percent of the cost of a worst-case accident – with taxpayers covering the remaining 98 percent.[82]

The full value of this subsidy is difficult to estimate, but it is substantial. If nuclear operators had to carry the full cost of insurance, the plants would most likely become uneconomic to build.

Shifting Risk onto Customers

Even given nuclear power companies' efforts to dip into public coffers, many investors are still hesitant to take on the risk of financing such a massive project.[84] As a result, many utilities are also asking their customers to shoulder a significant share of the risk.

Charging Consumers Up Front

Traditionally, utility companies in states with regulated electricity markets have carried the costs of power plant development themselves, charging customers only after a plant was finished and able to deliver electricity. However, utilities wishing to build nuclear power plants are now reaching into their customers' pockets much earlier, creating special charges to help finance new nuclear plants before construction begins – with no guarantee of final cost, or even a guarantee that the plant will ever deliver electricity at all.

For example, Florida regulators are allowing Progress Energy to start billing customers up front for the planning, development and construction of two nuclear power plants in Levy County. As a result, Florida customers will begin paying more than $100 per year in higher electricity bills starting in 2009, even though the plant will not begin delivering electricity until 2016 at the earliest. Progress Energy CEO Jeff Lyash estimated that customers' monthly bills could increase 3 to 4 percent a year beyond that, with a potential spike as plant construction intensifies.[85] Residential customers could end up paying as much as $25 more a month to finance the nuclear reactors – equivalent to $300 a year.[86]

Progress Energy is not the only company turning to its customers for advance loans. South Carolina Electric & Gas plans to phase in a 37 percent rate hike to help cover the finance costs for a new reactor.[87] Santee Cooper, a publicly owned South Carolina utility, is following suit.[88] Ameren has requested a rate increase in Missouri, which critics allege is linked to an effort to overturn a law preventing utilities from charging consumers upfront for new power plant construction.[89] The utility claims that unless the law is repealed, it will not be able to afford to construct a new reactor.[90] And Georgia Power has dispatched its lobbyists to Atlanta to win approval for charging $1.6 billion in financing costs to its customers during the proposed construction of two new reactors at the Vogtle nuclear power plant – a plant that exceeded its original construction budget by 1,200 percent.[91]

Signing Long-Term Contracts

States with "deregulated" electricity markets pose greater challenges for nuclear power plant development, because risks are higher that a power plant developer will not be able to recover its costs from consumers.[92] To reduce this risk, companies attempting to build nuclear power plants in such areas are likely to seek long-term power purchase contracts from large customers.

For example, AREVA (a French government-supported nuclear developer) secured 60-year electricity supply contracts from a series of local utilities and forestry product companies near its prototype reactor in Finland, which agreed to take on some of the investment and operation risks in exchange for a guaranteed price of power.[93]

Long-term contracts are a useful tool for electric distribution utilities to obtain price certainty for their customers. However, with nuclear power, the price may not be right. Depending on the terms of the contract, customers could end up finding themselves tied to a sinking ship.

Credit Rating Penalties and Increased Finance Costs

Utilities taking on the construction of a new nuclear power plant, or signing a long-term contract, may find that the level of financial risk could lead to a credit rating penalty. Ultimately, consumers pay the price for lower credit ratings, because the company will have to pay higher interest rates on any loans – increasing the cost of power.

Undertaking the construction of a nuclear power plant requires a large amount of debt, and can negatively affect a company's credit rating.[94] Moreover, credit agencies treat long-term contracts effectively as debt. Large contracts can lead to a credit rating penalty if they leave utilities overexposed.[95]

Nuclear Engineering International notes that "faced with a lower credit rating, there aren't many company boards that would give the go-ahead to a new nuclear plant."[96]

Building a New Generation of Nuclear Reactors Would Cost Hundreds of Billions of Dollars

Electric power companies have announced 34 possible new nuclear reactors.[97] For 30 of these reactors, companies have publicly notified the Nuclear Regulatory Commission of their interest in applying for an official license to proceed.[98] Building these 30 reactors could require an investment larger than $300 billion.

Potential New Reactors

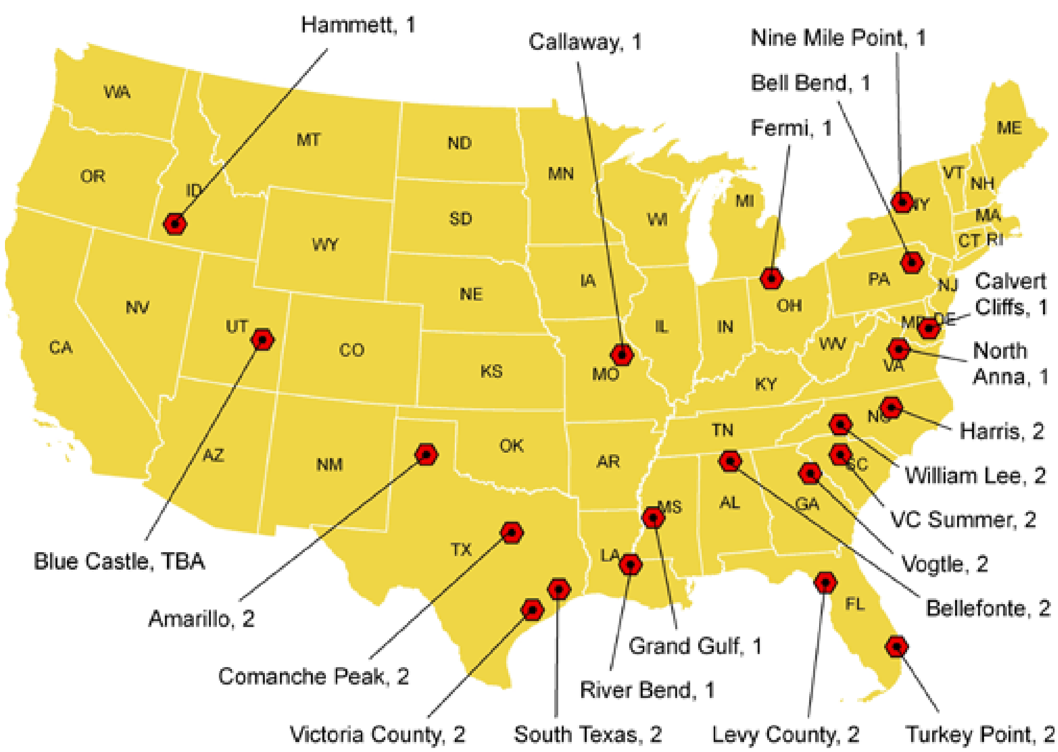
The U.S. Department of Energy (DOE) has identified 30 possible new nuclear reactor units, as of February 2009.[99] In each of these instances, a power company has notified the U.S. Nuclear Regulatory Commission (NRC) of its interest in applying for a license to build and operate a new reactor and selected a specific site and technology for the reactor. (Table 1 presents a list of the potential nuclear power projects by state, and Figure 2 places select projects on a map.)

Altogether, these 30 potential nuclear reactors would have an electricity generation capacity of 40,025 MW.[101] (That's roughly enough to power 40 million homes under today's electricity usage patterns.)

Billions in Investment

After reviewing five recent license applications in May 2008, Moody's In-

Figure 2: Locations of Selected Proposed Nuclear Reactors, and Number of Units Proposed[102]



vestor Service estimated that the capital cost of a new reactor, including finance costs, could reach $7,500 per kW.[103] At that price, the 20 potential new nuclear power plants would require a $300 billion investment over the coming decade.

The proposed nuclear power plants for Texas alone could cost $69 billion. Proposed reactors for Florida and South Carolina could cost $34 billion (for each state). Table 2 lists the potential cost of proposed reactor projects by state.

To put this amount in perspective, $300 billion is:

- More than double the estimated cost to repair all the bridges in the U.S. road transportation system.[104]
- More than the estimated cost of bringing all American public school buildings into conformity with building standards.[105]
- Approaching the same level as the estimated cost to upgrade public water supply and sewage systems across America.[106]

$300 billion is also larger than the 2007 gross domestic product of 35 individual states – including Maryland, Colorado, Missouri, Alabama, or South Carolina.[107] Put another way, $300 billion is also 12 times larger than the annual budget of the U.S. Department of Energy.[108]

Given the massive scale of this investment, we should ask: are there cheaper, more effective ways to solve America's energy problems? The answer is, emphatically, yes.

Table 1: Potential New Nuclear Power Projects by State[100]

State	Number of Reactors	Total Capacity (MW)
Texas	6	9,140
Florida	4	4,468
South Carolina	4	4,468
Alabama	2	2,234
North Carolina	2	2,234
Georgia	2	2,234
Pennsylvania	1	1,600
Idaho	1	1,600
Missouri	1	1,600
Maryland	1	1,600
New York	1	1,600
Michigan	1	1,520
Mississippi	1	1,520
Virginia	1	1,520
Louisiana	1	1,520
Tennessee	1	1,167

Table 2: Potential Cost of Proposed Reactor Projects by State

State	Number of Possible Reactors	Potential Cost ($ Billion)
Texas	6	$69
Florida	4	$34
South Carolina	4	$34
Alabama	2	$17
North Carolina	2	$17
Georgia	2	$17
Pennsylvania	1	$12
Idaho	1	$12
Missouri	1	$12
Maryland	1	$12
New York	1	$12
Mississippi	1	$11
Virginia	1	$11
Louisiana	1	$11
Tennessee	1	$9

Dollar for Dollar, Clean Energy Can Deliver More Energy than Nuclear Power

Expanding nuclear power is not the only option to address America's energy problems. We could also create an innovative, new electricity system based on highly efficient and targeted use of power, generated by a diverse set of modular, clean and widely distributed resources.

This course would include highly efficient homes, businesses and factories – improving the reliability of electricity service while minimizing investment in expensive infrastructure. In addition, this course would build America's capacity to generate electricity from renewable sources of energy – from the movement of the wind to the heat of the sun and the earth.

These clean energy solutions can deliver more power per dollar of investment than a new generation of nuclear power plants. Even the most optimistic estimates for the cost of power from a new nuclear reactor are 300 percent higher than the cost of energy efficiency. Nuclear power is more than 200 percent costlier than combined heat and power technologies. And nuclear power is more than 50 percent more expensive than new onshore wind power, and – at best – comparable to new offshore wind power.

The cost advantages clean energy has over nuclear power are likely to become even more pronounced over time. According to Moody's Investor Service, "…nuclear generation has a fixed design where construction costs are rising rapidly, while other renewable technologies are still experiencing significant advancements in terms of energy conversion efficiency and cost reductions."[109]

As a result, nuclear subsidies could be more profitably directed into more cost-effective energy efficiency and renewable energy programs.

America Has Enormous Clean Energy Potential

America has enormous potential to save electricity through energy efficiency, and to generate electricity through clean and renewable resources, from recycling waste energy to tapping into wind and solar power. America's potential resources vastly exceed our annual electricity needs, and represent the equivalent of thousands of nuclear reactors.

- Vast "strategic reserves" of energy efficiency exist within America's homes, businesses and industrial facilities. For example, many light fixtures give off excess heat; air fans operate without the benefit of efficient motors; weaknesses in building insulation allow indoor heat to escape. Opportunities to improve energy efficiency also include combined heat and power (CHP) technology, which captures waste heat from electricity generation and puts it to use.[110] Similarly, waste heat from industrial processes can be used to generate pollution-free electricity.[111] Altogether, the American Council for an Energy-Efficient Economy – composed of some of the nation's leading experts on energy efficiency – estimates that the United States could cost-effectively reduce its overall energy consumption by 25 to 30 percent or more over the next 20 to 25 years.[112] Progress at this level would ensure that America uses less energy several decades from now than we do today, even as our economy grows. At this rate, America would save more than 1 million gigawatt-hours (GWh) of electricity in 2030, equivalent to the output of more than 100 nuclear reactors.[113]

- America also has vast reserves of wind power. The nation's cumulative wind power potential has been estimated at upwards of 10 trillion kilowatt-hours annually – more than twice the amount of electricity currently generated in the United States.[114] The Western Governors Association (WGA) estimates that from Texas to Washington State, potential wind resources could support 250,000 MW at competitive prices, equivalent to the energy output of more than 60 nuclear reactors.[115] Offshore wind energy holds massive additional potential as an electricity source.[116]

Photo: NREL

- America has a great deal of potential to generate electricity from the energy of the sun – whether by capturing its heat, or directly transforming light into electricity. Solar thermal power plants have a special advantage over other types of renewable technologies. They can be designed to store heat collected from sunlight during the day, enabling the plant to produce electricity whenever it is needed, even during cloudy weather or at night.[117] Solar thermal power plants covering a 100-mile-square area of the Southwest – equivalent to 9 percent the size of Nevada – could generate enough electricity to power the entire nation.[118] In addition to solar thermal power, the United States could generate electricity using solar photovoltaic (PV) technology to directly transform light into electricity. Installing solar panels on only 7 percent of the land area currently used for buildings, parking lots and other built-up areas could deliver the equivalent of the nation's entire electricity needs.[119]

America could generate a great deal of additional electricity using the earth's heat, currents in the ocean, and biomass fuel.

- Using today's technology, the United States could provide as much as 25 to 50 gigawatts of additional electric generating capacity from geothermal energy, roughly equivalent to all currently proposed nuclear reactors discussed in this report.[120] Using tomorrow's technology, geothermal power could provide stable, round-the-clock electricity anywhere in the country.[121]
- A tremendous amount of energy exists just off our shores in the movement of ocean waters. For example, the Gulf Stream current in the Atlantic Ocean flows through the Straits of Florida and along Florida's Atlantic coast. The energy in the Gulf Stream is the equivalent of 20,000 times the energy in Niagara Falls, with a flow of water 50 times more than the volume of all the world's freshwater rivers combined.[122] Capturing just a fraction of this energy could supply Florida's entire energy needs.[123]
- Plant-based sources of energy, called "biomass," already provide a substantial amount of energy in America and can provide even more. 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.[124]

Photo: NREL

Clean Energy Solutions Cost Less than Nuclear Power

As noted earlier, Moody's May 2008 cost estimate for nuclear power implies that reactor owners would have to sell electricity at an average of 15 cents per kWh over the life of the plant in order to earn an adequate profit.

Vast amounts of clean energy are available at far less cost.

Increasing Efficiency and Eliminating Waste is the Cheapest Source of Electricity

Improving the energy efficiency of our economy is the cheapest and fastest way to address America's energy problems.

Saving energy through efficiency measures is much cheaper than generating and delivering electricity. In leading states, energy efficiency supplies most new electricity needs – cutting projected consumption by 1 to 2 percent each year at a cost of less than 3 cents per kWh.[125] In comparison, a typical American family pays more than 10 cents per kWh for electricity.[126]

Analyses of future energy efficiency potential typically find vast available resources with average levelized costs of around 4 cents per kWh in the residential sector and 2 cents per kWh or less in the commercial and industrial sectors.[127] For example, recent studies of energy efficiency potential in Maryland and Florida found that the states could reduce electricity consumption by as much as 30 percent below forecast levels by 2025, at average costs around 3 cents per kWh.[128] Studies by the electric power industry concur. For example, Commonwealth Edison calculated that an aggressive efficiency program in Illinois could save more than 1,000 GWh of electricity per year at a cost of only 2.5 cents per kWh.[129] Moreover, as the scale and scope of energy efficiency programs increase, they tend to become even more cost effective.[130]

Combined heat and power and recycled energy technologies are also extremely cost-effective sources of electricity. Recycled energy technologies can generate electricity for about 3 cents per kWh.[131] Combined cycle industrial heat and power installations can generally produce power for 4.5 to 5.5 cents per kWh, including credit for the value of useful heat that the generators also produce.[132] And smaller building-scale CHP technology can deliver electricity for less than 6 cents per kWh, again counting the value of the useful heat also produced by the generator.

Photo: Paul Adam Smith

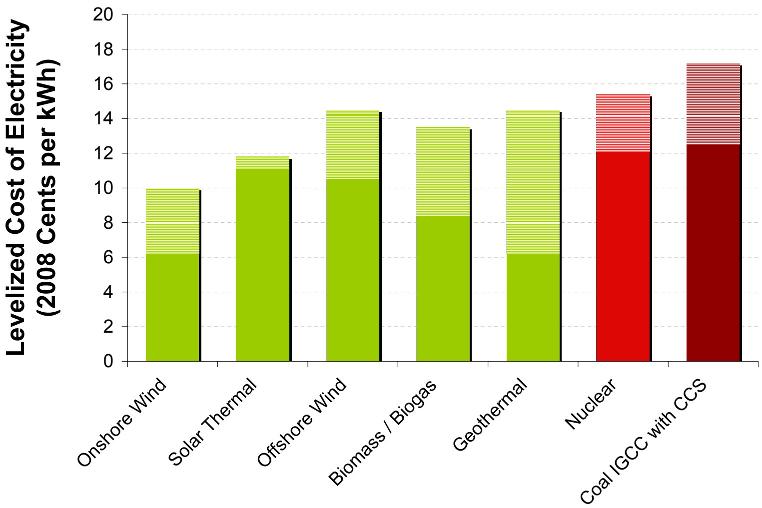
For example, Beloit Memorial Hospital in Beloit, Wisconsin, installed a CHP system while upgrading its electrical distribution system in the 1990s. The CHP technology allows the hospital to provide its own electricity, and heat for internal hospital systems, at between 1.8 and 2.3 cents per kWh (2002 dollars).[133]

CHP systems can significantly reduce energy bills. For example, San Mateo Community College District in California installed two combined heat and power units to generate electricity and heat for two of its campuses. Coupled with several energy efficiency upgrades, the combined heat and power system reduced the district's electricity usage by more than 50 percent and cut energy bills by more than $1 million per year.[134]

Energy efficiency and combined heat and power have the added advantage of saving or generating energy near where it will be used. This avoids the added cost for transmitting and distributing electricity from a central power plant, which can exceed 2 cents per kWh. In addition, saving or generating energy locally minimizes electricity losses that can occur while transporting electricity from a distant power plant.

Energy from a new nuclear reactor would be – at best – two to five times more expensive than these energy sources.

Figure 3: Estimated Cost of Electricity from Low-Carbon Renewable, Nuclear, and Coal Generation Technologies (Levelized)[136]



This figure compares estimated costs of electricity generation from different low-carbon generation technologies, levelized (or averaged) over the lifetime of the technology to enable a meaningful comparison. The striped portion of the bar represents the possible range of costs, which varies with the type of technology used, the quality of the natural resource, and also the precision of cost estimates. Each bar includes estimated transmission interconnection costs, but not distribution costs. Values for energy efficiency, combined heat and power, nuclear and coal are not specific to any particular location. Wind energy estimates represent the average resource for the U.S. as a whole. Estimates for solar thermal represent typical resources in the southwestern United States. The cost estimates for solar thermal, biomass, geothermal, nuclear and coal were produced for the California Public Utilities Commission, while cost estimates for wind energy were generated by the United States Department of Energy. (IGCC with CCS stands for integrated gasification combined cycle with carbon capture and sequestration, a potential method of producing effectively low carbon electricity from coal.)

Large Amounts of Renewable Energy Can be Delivered for Less Cost than Nuclear Power

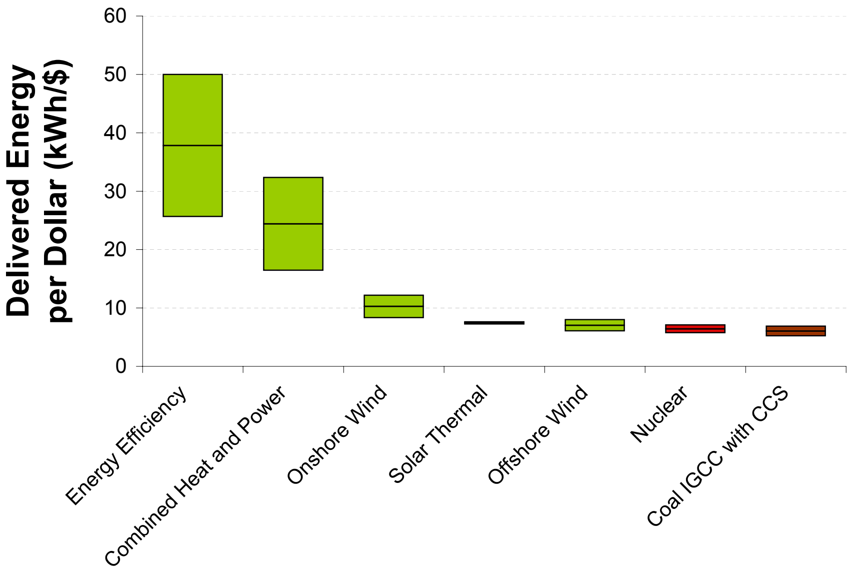
Research done for the California Public Utilities Commission (CPUC) at the end of 2007 provides a relatively recent, apples-to-apples comparison of the costs of different generation technologies. The estimates are partially specific to western states, but give a useful idea of how nuclear energy stacks up against renewable energy and other generation technologies.

The research for the CPUC puts the levelized cost of new nuclear power at 12.1 to 15.4 cents per kWh (2008 dollars, including interconnection and firming costs, but not distribution costs).[135] These values are based on the U.S. Department of Energy's *Annual Energy Outlook 2007*, with upward adjustments for the declining value of the dollar and for recent commodity price increases. They are still more optimistic than many of the estimates discussed earlier in this report.

In comparison, power from a new nuclear reactor would be about 60 percent more expensive than onshore wind power and geothermal energy and 20 percent more expensive than solar thermal or biomass power, on average. (See Figure 3.)

Finally, nuclear – at best – would be comparable in price to power from an offshore wind farm. For example, Delmarva Power signed a contract in June 2008 with a developer planning a wind farm off the coast of Delaware. Under this contract, Delmarva agreed to pay 11.7 cents per kWh for 200 MW worth of power from this facility.[137] However, this is a signed contract – with more cost certainty than a new nuclear reactor.

Figure 4: Electricity Delivered to the Consumer per Dollar of Investment (Levelized) – A Comparison of Select Low-Carbon Energy Technologies[144]



This figure presents the amount of electricity delivered to the consumer per dollar of investment in different energy technologies, with the investment per unit of energy production "levelized" (or averaged) over the lifetime of the technology to enable meaningful comparison. Each bar represents the range between high and low productivity estimates, accounting for differences in the technology used, variability in the quality of the natural resource, and the precision of cost estimates. Each bar includes an estimated cost to deliver electricity to the consumer, except for efficiency and combined heat and power, which act locally. Values for energy efficiency, combined heat and power, nuclear and coal are not specific to any particular location. Wind energy estimates represent the average resource for the U.S. as a whole. Estimates for solar thermal represent typical resources in the southwestern United States. The cost estimates for solar thermal, biomass, geothermal, nuclear and coal stem from an analysis produced for the California Public Utilities Commission, while cost estimates for wind energy stem from analysis by the United States Department of Energy. (IGCC with CCS stands for integrated gasification combined cycle with carbon capture and sequestration, a potential method of producing effectively low carbon electricity from coal.)

The Effect of Future Laws Limiting Global Warming Pollution

The nuclear industry has claimed that future laws limiting global warming pollution will give nuclear power an advantage over its competitors. That is true only when comparing nuclear power to coal- or gas-fired power plants. Clean energy solutions, which also emit minimal to zero global warming pollution, should receive a similar advantage under future climate legislation that limits emissions of carbon dioxide. In other words, nuclear power will not gain ground on its main competitors.

Energy efficiency is at least 300 percent more cost-effective at displacing carbon emissions, and wind power and building-scale combined heat and power are on the order of 150 percent more cost-effective than nuclear power.[145] These technologies can help America reduce its contribution to global warming much more quickly and cost-effectively than nuclear power.

Altogether, the California Public Utilities Commission estimates that, in the Western United States:[138]

- Nearly 200,000 GWh per year of renewable electricity could be delivered locally for 9 cents per kWh or less;
- An additional 200,000 GWh per year of renewable electricity could be locally delivered at costs of 10 cents per kWh or less; and
- Well over 500,000 GWh per year of additional renewable electricity could be delivered locally at a cost of 12 cents per kWh or less.

Altogether, this represents the equivalent energy output of well over 90 nuclear reactors.[139] And all of this electricity would be available for less than the best-case cost of power from a new nuclear power plant.

Energy Output per Dollar of Investment

Ultimately, the most important point of comparison between nuclear power and other energy technologies is at the point where the energy is used – a home,

Can Clean Energy Serve as a "Baseload" Power Source?

Power planners often refer to nuclear energy as a "baseload" resource. By this, they mean that nuclear reactors generate power at relatively consistent levels over long periods of time, supplying power both during peak and non-peak periods.

Clean energy can be an equally effective and reliable source of electricity.

First, energy efficiency measures reduce demand for electricity both during peak and non-peak hours, and thus can effectively function as a "baseload" resource. America's energy efficiency resources are vast – effectively the equivalent of more than 100 nuclear reactors operating by 2030. Efficiency measures are generally faster to deploy and greatly contribute to the overall reliability of the electricity grid.

Additionally, large-scale renewable energy technologies can make meaningful contributions to the electricity grid, even though available power varies depending on the wind speed, time of day, or cloud cover at the time. Nations such as Denmark have shown that it is possible to obtain as much as 20 percent of electricity supplies from wind (and even more at certain times and places). And the Minnesota Public Utilities Commission found that utilities can obtain up to one-quarter of their electricity from wind without harming grid reliability, and with only minor costs for absorbing the intermittent power.[146]

Moreover, thoughtful deployment of combinations of different renewable energy technologies in different places can reduce the variability of power output and make it possible to rely less on traditional "baseload" sources of power such as coal and nuclear. For example, researchers at the Rocky Mountain Institute and the University of Colorado found that an optimized portfolio of wind and solar power, in as few as six locations, can reduce the variability of overall power output by more than half.[147]

Moreover, renewable resources including solar thermal with energy storage, geothermal, and biomass energy can serve as traditional sources of baseload electricity generation.
Future advances in demand response, energy storage, and advanced technologies such as enhanced geothermal energy will enable renewable resources to become an even larger part of America's electricity supply.

a business, or a factory. At this level, clean energy solutions stand out. Dollar for dollar, an investment in clean energy will yield more electricity than an equivalent investment in nuclear power. (See Figure 4 and note 136 for details.)

- A dollar invested in energy efficiency would yield greater than five times more electricity than a dollar invested in nuclear power.
- Similarly, a combined heat and power facility could generate nearly four times the electricity per dollar compared to a nuclear power plant.
- Investing a dollar in wind power would yield between 20 and 100 percent more energy than a comparable investment in nuclear power, depending on the quality and location of the wind resource.
- And a solar thermal power plant in the southwestern U.S. – capable of storing heat to generate electricity even when the sun isn't shining – can deliver as much as one-third more energy than a nuclear reactor, and, at worst, can equal the energy output of a nuclear reactor per dollar of investment.

These facts are reflected in the conclusion of a recent report by the European Renewable Energy Council, the German Aerospace Center and Greenpeace, which shows that currently available clean energy technology could be deployed in the United States to deliver massive reductions in global warming pollution – at half the cost and with twice the job creation as an equivalent amount of nuclear and coal-fired power. Similarly, the Nuclear Policy Research Institute and the Institute for Energy and Environmental Research have published a report demonstrating how the United States can

"Costs are coming down, and they're coming down more rapidly than I would have thought."

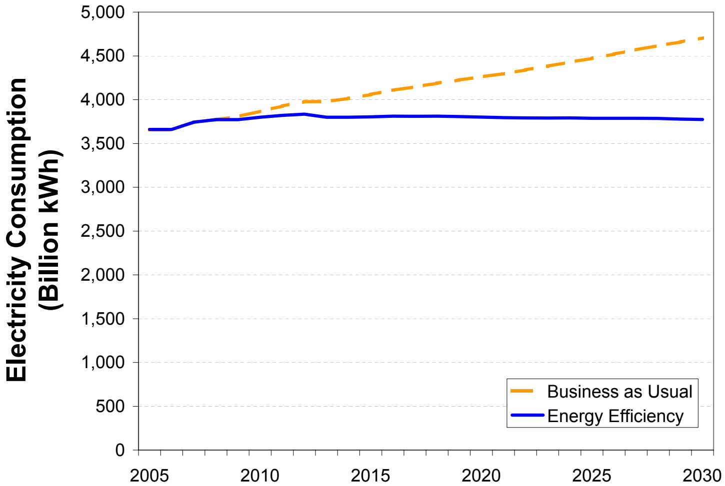
– Lew Hay, Chief Executive of FPL Group, Inc., June 25, 2008. FPL is planning to build 110 MW of solar photovoltaic and solar thermal power plants in Florida.[143]

Solar Photovoltaic Power is Quickly Becoming Cost-Competitive

While solar photovoltaic power can currently only compete with simple-cycle natural gas – a resource normally only used during periods of very high demand – the technology is rapidly advancing, and cost decreases are likely in the future. For example, Nanosolar, a firm backed by Google, has built two manufacturing facilities capable of producing 430 MW of solar capacity per year, using a process analogous to printing newspapers, effectively spraying solar cells onto a thin roll of sheet metal. Nanosolar panels cost under $1,000 per kW to manufacture.[140] At that price, solar photovoltaics begin to approach current nuclear cost estimates.[141]

This cost improvement is apparent in recent utility decisions to build nearly 1 GW of large-scale solar photovoltaic power plants in Florida and California – 10 times bigger than any now in service across the world.[142]

Figure 5: The Impact of a $300 Billion Investment in Energy Efficiency on U.S. Electricity Consumption



create an economy with zero emissions of global warming carbon dioxide pollution within 30 to 50 years at a reasonable cost, without nuclear power.[148]

What a $300 Billion Investment in Clean Energy Could Deliver

Investing $300 billion in cost-effective clean energy solutions, such as energy efficiency, could eliminate the need for any new nuclear power plants.

Energy Efficiency

Investing $300 billion in energy efficiency measures could completely alleviate the need to build any new nuclear power plants – and more.

At a levelized cost of 3 cents per kWh, a $300 billion investment in energy efficiency would save more than 10 million GWh of electricity in total. At this level of investment, America's annual electricity consumption could be nearly 20 percent below forecast levels by 2030 – no greater than it is today.[149] (See Figure 5.)

If consumers normally pay 9 cents per kWh for electricity, the energy saved through this energy efficiency investment would save consumers a net of more than $600 billion in energy purchases over time.[150] Energy savings in 2030 would be equivalent to the output of more than 80 nuclear reactors.[151]

Renewable Energy

Alternatively, $300 billion could buy enough wind turbines or solar thermal power facilities to supply on the order of 10 percent of America's projected electricity needs in 2030.

With an expected 2008 installed cost of around $1,900 per kW, $300 billion could build wind farms with a generation capacity of more than 150 GW.[152] That many wind turbines would be capable of generating more than 450,000 GWh of electricity per year, or close to 10 percent of America's projected annual consumption in 2030 – equivalent to the output of more than 40 nuclear reactors.[153]

Putting $300 billion into solar thermal power, at today's estimated capital cost of $3,600 per kW, would yield more than 80 GW of solar thermal power plants in the southwestern U.S., with up to 6 hours of thermal storage capability.[154] These plants could produce nearly 300 GWh per year, or just over 6 percent of America's projected annual consumption in 2030 – equivalent to the output of more than 30 nuclear reactors.[155]

And this is assuming that current capital costs for wind turbines and solar thermal power plants do not change. As economies of scale begin to develop, it is quite possible that a dollar invested in these technologies will travel even further.

Conclusions and Recommendations

Nuclear power is one of the least cost-effective ways to address America's energy problems. In comparison, other low-carbon energy sources – including energy efficiency, wind power, solar power and geothermal energy – deliver more results for every dollar of investment.

This fact has important implications for America's energy policy. By directing resources toward the most cost-effective solutions, we can make greater progress toward a secure, reliable and safe supply of electricity to power America's economy.

America should reform its energy policy to prioritize clean energy solutions – technologies that deliver safe, reliable and secure electricity supplies at a reasonable cost.

- State leaders should **protect citizens from unnecessary risks** by requiring any company proposing to build a new nuclear reactor to demonstrate that nuclear power generation would be more cost-effective than other ways to meet electricity demand, including energy efficiency, before allowing construction to proceed. Evaluations of cost-effectiveness should be conducted by an unbiased, independent, reputable agency and be available for public review.
- State and national leaders should **ensure that energy companies and their shareholders, not rate-payers or taxpayers bear all of the financial risks** associated with building a new nuclear power plant. In particular, regulators should not allow consumers to be charged up-front to finance the construction of a new nuclear reactor. Congress should also repeal the Price Anderson act, under which taxpayers shoulder the lion's share of responsibility for any major nuclear accident, and ensure that reactor owners bear the full cost of safe disposal of nuclear waste and reactor decommissioning.

- State and federal regulators should **provide full opportunity for public input** at every key point in the process of developing any new nuclear reactor.
- America should **shift current federal subsidies away from nuclear and fossil fuel energy**, creating billions annually for research, development and deployment of more effective energy efficiency and renewable energy technologies.
- America should speed the introduction of clean energy technologies by enacting a national **energy efficiency resource standard** to require, at minimum, that all new demand for electricity be met with energy efficiency measures. . Energy efficiency programs across the country have proven effective in saving substantial amounts of electricity and natural gas, saving consumers money, reducing energy prices, eliminating the need to build expensive new power plants, creating jobs, and improving local economies.[156] For example, between 2001 and 2005, New Jersey's efficiency programs reduced electricity demand enough to replace a medium-sized power plant (450 megawatts).[157] In 2007 alone, Vermont reduced its electricity consumption by 1.8 percent below forecast levels, at a fifth of the cost of building new power plants and power lines.[158] And in Connecticut, every dollar spent on energy efficiency yields $4 in consumer savings.[159]
- America should enact a federal **renewable electricity standard** to ensure that 25 percent of the national electricity supply comes from renewable resources by 2025.
- States should also create or expand analogous policies to promote clean energy at the state level.

Notes

1. This figure actually underestimates the degree to which nuclear projects exceeded budget targets. It excludes escalation and finance costs incurred by construction delays, and does not include data from some of the most over-budget reactors. See Congress of the United States, Congressional Budget Office, *Nuclear Power's Role in Generating Electricity*, May 2008, based on data from U.S. Department of Energy, Energy Information Administration, *An Analysis of Nuclear Power Plant Construction Costs*, Technical Report DOE/EIA-0485, 1 January 1986.

2. The Vogtle plant in Georgia, which began producing electricity in the late 1980s, cost $8.87 billion to build. Its original construction budget was on the order of $660 million. See Jon Gertner, "Atomic Balm?" *The New York Times Magazine*, 16 July 2006; David Schlissel and Bruce Biewald, Synapse Energy Economics, Inc., *Nuclear Power Plant Construction Costs*, July 2008.

3. J. Cook, "Nuclear Follies," *Forbes*, February 1985.

4. In the 1990s, stranded costs were estimated in the hundreds of billions. See: Moody's Investors Service, *Stranded Costs Will Threaten Credit Quality of U.S. Electrics*, August 1995.

5. As quoted in "Power Struggle; Nuclear Energy," *The Economist*, 6 December 2008.

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