BLUEPRINT FOR 100 NEW NUCLEAR POWER PLANTS IN 20 YEARS

HOW NUCLEAR POWER CAN PRODUCE ENOUGH CLEAN, CHEAP, RELIABLE, AMERICAN ENERGY TO CREATE JOBS, CLEAN THE AIR, AND SOLVE GLOBAL WARMING

Lamar Alexander, Chairman
U.S. SENATE REPUBLICAN CONFERENCE

Republican United States Senators have agreed upon a plan for low cost clean energy that includes —

**Building 100 nuclear power plants within 20 years*

**Electric cars and trucks for conservation*

**Offshore exploration for natural gas and oil*

**Double energy research and development*

In furtherance of that plan, I offer this blueprint for how to build 100 new nuclear power plants within 20 years.

I would welcome your comments and suggestions at www.alexander.senate.gov.

Lamar Alexander

Chairman, U.S. Senate Republican Conference

July 20, 2009

A Moment of Reflection/ A Call to Action

With the Waxman-Markey climate change and energy bill (American Clean Energy and Security Act) now passed by the House of Representatives and moving to the Senate, we need to take a moment to reflect on exactly what it is we are trying to accomplish with this legislation.

What kind of America do we hope to create in the next 20 years?

- We want an America in which we have enough clean, cheap, and reliable energy to create good jobs and run a prosperous industrial and high-tech society. In order to support the American economy that creates about 25 percent of the world's wealth, we need to produce about 25 percent of the world's energy.

- We want an America in which we are not creating excessive carbon emissions and running the risk of encouraging global warming.

- We want an America with cleaner air – where smog in Los Angeles and in the Great Smoky Mountains is a thing of the past – and where our children are less likely to suffer asthma attacks brought on by breathing pollutants.

- We want an America in which we are not creating "energy sprawl" by occupying vast tracts of farmlands, deserts, and mountaintops with energy installations that ruin scenic landscapes. The Great American Outdoors is a revered part of the American character. We have spent a century preserving it. We do not want to destroy the environment in the name of saving the environment.

- We want an America in which we create hundreds of thousands of "green jobs" but not at the expense of destroying tens of millions of red, white, and blue jobs. It doesn't make any sense to employ people in the renewable energy sector if we are throwing them out of work in manufacturing and high-tech. That's what will happen if these new technologies raise the price of electricity and send manufacturing and other energy-intensive industries overseas searching for cheap energy. We want new, clean, energy-efficient cars, but we want them built in Michigan, Ohio, and Tennessee, not Japan and Mexico.

- We want an America where we are the unquestioned champion in cutting-edge scientific research and lead the world in creating the new technologies of the future.

- And we want an America capable of producing enough of our own energy so that we can't be held hostage by some other energy-producing country.

None of these goals are met by the Waxman-Markey bill. What started out as an effort to address global warming by reducing carbon emissions has ended up as a huge and unnecessary burden on the economy, a $100 billion a year job-killing national energy tax that will create a new utility bill for every American family.

This tax burden is relieved only by the vague hope that all this can be overcome by mandating increased use of a few alternative energy sources defined as "renewable." Renewable energies such as wind, solar, and biomass are intriguing and promising as a supplement to America's energy requirements. Yet the Waxman-Markey bill proves once again that one of government's biggest mistakes is taking a good idea and expanding it until it doesn't work anymore.

Trying to expand these forms of renewable energy to the point where they become our prime source of energy has huge costs and obvious flaws that may be impossible to overcome. What's worse, such an effort in renewable energy creates a whole new problem – "energy sprawl" – where we are asked to sacrifice the American landscape and overwhelm fragile ecosystems with thousands of massive energy machines in an effort to take care of our energy needs.

Is this really the America we want?

There's a better option. Let's take another long, hard look at nuclear power. Nuclear is already our best source for large amounts of cheap, reliable, and clean energy. It provides only 20 percent of our nation's electricity but 70 percent of our carbon-free, pollution-free electricity. It is already far and away our best defense against global warming.

So why not build 100 new nuclear power plants during the next 20 years? American utilities built 100 reactors between 1970 and 1990 with their own (ratepayers') money. Why can't we do it again? Other countries are already forging ahead of us. France gets 80 percent of its electricity from 50 reactors and has among the cheapest electricity rates and the lowest carbon emissions in Europe to show for it.

Japan is building reactors from start to finish in four years. China is planning 60 new reactors while Russia is selling its nuclear technology all over the world. India is making plans. President Obama has even said Iran has the right to use nuclear power for energy. We invented this technology. Isn't it time we got back in the game?

There seem to be two things holding us back:

1. An exaggerated fear of nuclear technology.

2. A failure to appreciate just how different nuclear is from other technologies – how its tremendous energy density translates into a vanishingly small environmental footprint.

Both these subjects are discussed at length in this *Blueprint*. This document also addresses the costs of nuclear and dispels the notion that nuclear energy requires vast amounts of government subsidies.

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Nuclear power is the obvious first step to a policy of clean but low-cost energy. One hundred new plants in 20 years would double U.S. nuclear production, making it about forty percent of all electricity production. Add 10 percent for sun and wind and other renewables, another 10 percent for hydroelectric and maybe 5 percent more natural gas – and we begin to have a cheap as well as clean energy policy.

Step two for a cheap and clean energy policy is to electrify half our cars and trucks. There is so much unused electricity at night that we could do this right now without building one new power plant, if we plug in vehicles while we sleep. Of course, that would increase our coal usage, which is why we also need more nuclear power. This is the fastest way to reduce dependence on foreign oil, keep fuel prices low, and reduce the one third of the carbon dioxide that comes from gasoline engines.

Step three is to explore offshore for natural gas (it's low-carbon compared to coal) and oil (using less, but using our own).

The final step is to double funding for energy research and development and launch several mini-Manhattan projects like the one we had in World War II, this time to meet seven grand-energy challenges: improving batteries for plug-in vehicles, making solar power cost competitive with fossil fuels, making carbon capture a reality for coal-burning plants, safely recycling used nuclear fuel, making advanced biofuels (from crops we don't eat) cost-competitive with gasoline, making more buildings green buildings and providing energy from fusion.

The difficulties with nuclear power are political not technological, social not economic. The main obstacle is a lingering doubt and fear in the public mind about the technology. Any progressive Administration that wishes to solve the problem of global warming without crushing the American economy should help the public resolve these doubts and fears. What is need boils down to two words: presidential leadership.

We can't wait any longer to start building our future of clean, reliable and affordable energy. The time has come for action. We can revive America's industrial and high-tech economy with the technology we already have at hand. The only requirement is that we open our minds to the possibilities and potential of nuclear power.

As we do, our policy of cheap and clean energy based upon nuclear power, electric cars, offshore exploration, and doubling energy R&D will relieve strained family budgets and a sick economy with 10 percent unemployment. It will also prove to be the fastest way to increase American energy independence, clean the air, and reduce global warming.

Lamar Alexander
Chairman, Senate Republican Conference
July 13, 2009

Blueprint for 100 New Nuclear Power Plants in 20 Years

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The Power of the Atom

<u>*Nuclear Power's Remarkable Energy Density*</u>. Nuclear energy may be the greatest scientific discovery of the 20th century. It is based on physics of the atom, which is the reason a large portion of the public does not yet understand it. It is difficult to grasp how an energy source can be so powerful and still have so little impact on the environment. Yet if we were to describe the ideal energy source – low fuel requirements, no carbon emissions or other pollution, little land requirements, low cost, and large amounts of power – it would be nuclear energy.

Splitting a uranium atom yields ***two million times*** as much energy as breaking the carbon-hydrogen bond in coal. That means a few uranium fuel rods can produce the same amount of power as whole trainloads of coal. In fact, the traces of uranium in coal – about 0.03 percent of its weight – actually contain more potential energy than the coal itself. Instead of burning coal, it would be much better to "mine" it for uranium.

Low energy density is an even bigger problem when we come to renewable resources. What we are calling "renewables" are actually energy flows in nature, with far lower energy density than fossil fuels. Biofuels, for example, have about $1/4^{th}$ to $1/10^{th}$ the density of coal because they are "young coal" that has not compacted and aged in the earth for millions of years. Wind and solar are limited by the density of air and energy content of sunlight, which are substantial over vast areas, but are relatively weak on the scales of traditional energy sources. Only geothermal energy has a high density and that is because it is actually nuclear power emanating from deep within the Earth. The breakdown of uranium and thorium deep in the Earth, combined with the pressure of gravity, raises the temperatures at the center of the Earth to 7000 ^{o}C, hotter than the surface of the sun. When we build a nuclear plant, we are simply borrowing some of the Earth's natural heat and putting it in the controlled environment of a reactor. Nuclear power and geothermal power are essentially the same thing.

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A coal plant requires almost one train daily.

Energy density becomes hugely important when it comes to mining and transporting these fuels and disposing of their waste. A 1,000-megawatt coal plant is fed by a 110-car freight train arriving every 30 hours, 300 times a year. In one year the plant will throw 10 million tons of carbon dioxide into the atmosphere. Whole mountains are being decapitated and mile-wide holes dug in the ground in Wyoming or Montana to mine this coal. When sulfur and ash are removed by scrubbing, large reservoirs of sludge are produced that are a disposal problem in themselves. Yet this effort to clean coal of its pollutants will pale beside any attempt to capture carbon dioxide – the prime waste product – and store it in underground caverns. Carbon capture and sequestration will be the biggest engineering job ever attempted on the planet.

Now compare this to nuclear technology. A nuclear reactor is refueled when a half-dozen tractor-trailers arrive at the plant carrying new fuel rods once every 18 to 24 months. The rods are only mildly radioactive and can be safely handled with gloves. They will sit in the reactor for five years, producing no pollution or carbon emissions. When removed five years later, they will look exactly the same, just like a bundle of metal pipes – except now they are very radioactive. A few feet of lead or water blocks all radiation, however, so they can be stored safely in pools or lead-lined casks. Within three years they will lose half their radioactivity. After that, nuclear reprocessing can recycle most of the spent fuel rod into new fuel (we don't reprocess in this country – we'll discuss more of that later). Only 3 percent of the energy potential of a fuel rod is used in its first run-through. France, which has complete fuel reprocessing, now gets 30 percent of its reactor fuel from recycling. It also stores all its unusable radioactive waste from 30 years of producing 80 percent of its electricity beneath the floor of one room at their facility in La Hague.

All of France's nuclear waste from 30 years of producing 80 percent of its electricity is stored under this floor.

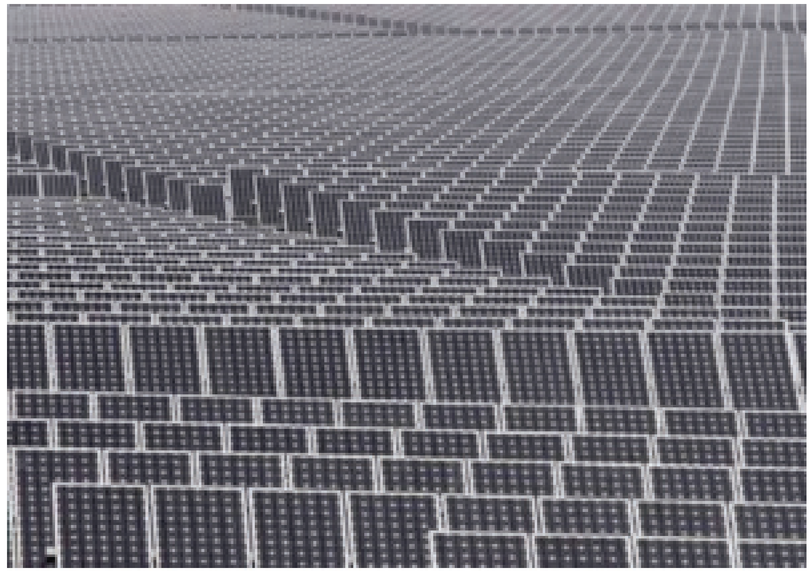
It is this off-the-scale energy potential that makes nuclear energy so hard to understand – and the subject of so much fearful speculation. When the uranium atom splits in two, about one-billionth of its mass is completely transformed into energy. Yet because of Einstein's famous equation, $E = mc^2$, this tiny amount of matter converts into ***one quadrillion times*** as much energy. A uranium fuel pellet the size of a thimble contains the energy equivalent of 1,780 pounds of coal, 149 gallons of oil, or 17,000 cubic feet of natural gas. After a fuel assembly completes its five-year cycle, only six ounces of the mass will have been completely converted into energy. Yet this energy will be enough to power a city the size of San Francisco for those five years.

Comparison to Fossil Fuels and Renewables. Wind, solar, and other renewables have energy densities that are incomparably smaller. Therefore their land requirements are stupendously

Some environmentalists have labeled mountaintop windmills energy sprawl.

larger. While a 1,000-megawatt nuclear reactor is powered by a fuel assembly that would fit into an average-sized living room, a 1,000-MW hydroelectric plant requires a reservoir 250 miles square. This is the reason environmentalists began opposing dam construction in the 1960s – because they took up so much space. Wind has less density and wind farms will have to cover 270 square miles to generate the same 1,000 MW of reliable electricity. Burning biomass (a controlled bonfire) to generate electricity will require about 800,000 acres of continuously farmed grassland or forest – an area larger than the Great Smoky Mountains National Park – to generate 1,000 MW. And any effort to harness the tides or ocean currents will face the same limitations. About 25 miles of coastline will be required to produce 1,000 MW.

Solar energy radiates from nuclear reactions in the Sun, but they occur 90 million miles away and are very dilute by the time they reach the earth. Solar energy gives us about 400 watts per square meter. Since the best technologies can convert only 25 percent of this to electricity, solar can give us one 100-watt bulb per average card table. This is a significant amount of energy. We should do everything we can to take advantage of it. Covering every square inch of rooftop in the country with solar collectors could probably provide enough power to run our indoor lighting and some household appliances during daylight hours.



Solar collectors will have to cover vast stretches of desert.

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Despite the weaknesses of solar and wind, both still have definite contributions to make therefore should be part of any energy plan. Solar electricity's great advantage is that it peaks during the hottest hours of the day and on summer afternoons, when customers are running their air conditioning and utility companies are straining to meet peak demand for power. Solar electricity would be ideal for meeting peak demand, now handled mostly by expensive gas turbines.

The problem arises when overenthusiastic supporters of solar and wind energy argue it can be used to meet ***base*** loads. Solar and wind electricity is ill suited to provide base-load power, which must run uninterrupted night and day (because today, electricity from solar and wind can't be stored). The Department of Energy has produced a report, titled "20% Wind Energy by 2030," that explains the intermittency problems of most renewable forms of generation. Without some way to store large amounts of electricity, there's no way to have more than 25 percent of our electricity provided by solar and wind. Something else must make up the other 75 percent. So, rather than torture solar technology by trying to turn it into base load, it would be much better to accept its real strength – meeting peak load needs. Wind can also serve as a supplementary source of power, but is not reliable enough to provide base loads.

For all these reasons, reducing carbon emissions will mean building nuclear plants to provide base load electricity until carbon capture and sequestration, or some other technology, can be developed to capture emissions from coal plants or until some unforeseen technological development makes it possible to use sun and wind for base load. Right now these alternatives are too uncertain and expensive. Only nuclear power offers the potential for reducing our impact on the environment, resolving the problem of climate change while producing large amounts of cheap, clean, and reliable electricity. The potential is there. We only have to address the unreasonable fears surrounding nuclear energy.

The Exaggerated Dangers of Nuclear Power

<u>*The Difference between Nuclear Power and Weapons*</u>. In 1942, Enrico Fermi, the Nobel-Prize-winning Italian physicist, created the world's first sustained nuclear chain reaction in a squash court beneath the football stands at the University of Chicago. Fermi's "pile" generated only enough power to light a 40-watt bulb, yet it remains the model for all nuclear reactors today. Fermi used natural uranium, where fissionable uranium-235 (U-235) is only 0.7 percent of the total. On the other end of the spectrum is bomb-grade uranium, in which U-235 makes up 90 percent of the total. But commercial reactors only use 4 percent U-235 for fuel – not 90 percent. Power reactor fuel is only a few percent more enriched than natural uranium ore. This difference between "reactor grade" (4 percent U-235) and "bomb grade" (90 percent) is the reason a reactor cannot explode like an atomic bomb.

Nuclear opponents have never quite given up the idea that a reactor is a bomb waiting to blow up. Anti-nuclear books carry titles like "The Silent Bomb" and "The Quiet Bomb" and an accident at a nuclear power plant is always described as a "potential nuclear holocaust." None of this has any truth. A nuclear power plant cannot blow up. There is simply not enough fissionable material.

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<u>*Nuclear Accidents*</u>. What can happen is that a reactor can overheat, like a car engine will seize up and melt if the radiator leaks or you run out of oil. This is what happened at Three Mile Island. A valve failed to close and water began to leak out of the reactor. When confused operators overrode the emergency cooling system and emptied the core, the fuel overheated and "melted down."

Yet even in the case of a meltdown, there is an ingenious fail-safe mechanism in all American designs that prevents a "runaway reactor." The chain reaction in the uranium fuel requires a "moderator" to slow down neutrons so they can be absorbed by the uranium atom. Any light element – hydrogen, helium, sodium or carbon – will do. American reactors use water – ***the same water that cools the core.*** If the cooling waters are lost, ***the reactor stops reacting.*** A reactor cannot become a "runaway" – which was the fictitious scenario of the movie "The China Syndrome."

The failure to incorporate this simple safety mechanism in a Soviet-designed reactor led to the world's greatest nuclear disaster, at Chernobyl. The Soviets did two terribly foolish things. First, they used carbon instead of water as the moderator. Carbon is flammable. When the reactor lost its coolant, it not only failed to shut down, it set fire to the carbon. Second, they didn't build a containment structure around the reactor. No American power reactor has ever been built without a concrete containment. These two hideous mistakes turned an incident not unlike Three Mile Island (where we ended up with a mess, but nobody got hurt) into a disaster. Chernobyl was a true "runaway reactor." When the carbon ignited, it burned for days, sending a column of radioactive smoke and debris all over the world. Ultimately, it's important to remember that an event like Chernobyl cannot happen at a U.S. reactor.

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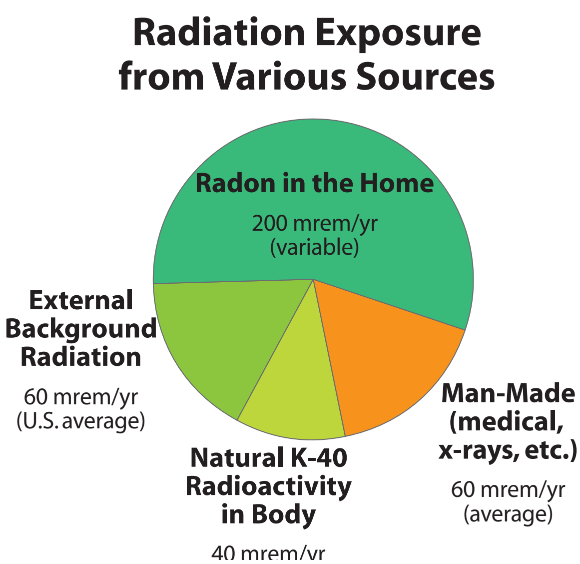
As bad as the Chernobyl event was, it didn't turn out to be the "nuclear holocaust" that it was originally expected to be by nuclear opponents. A UN report released on the 20th anniversary in 2006 found that 60 people had died. While these deaths are regrettable, they are much fewer than the number of people who die every year mining coal. Most of these were emergency workers and soldiers enlisted to clean up after the accident. Few of these recruits were given proper protective equipment. Some soldiers were sent onto the roof to throw off highly radioactive material with their bare hands and ultimately contracted cancer. There were also several thousand cases of thyroid cancer in surrounding populations, mostly among children. To be sure, no one wants anyone to suffer from cancer. But thyroid cancer is highly treatable, and ultimately few people died. Groups such as Greenpeace International continue to predict that 75,000 to 125,000 people will eventually die of cancer but this epidemic has never materialized.

Every American reactor is protected by a four-foot-thick concrete structure reinforced with thousands of steel rods. The containment is so strong it can withstand a jet plane hitting it at 500 miles per hour. People often ask, “What happens if terrorists hijack an airliner and crash it into a nuclear reactor?

Well if you want to see for yourself, go to YouTube and search for “Plane Crashing Into Wall.” In 1995, the Department of Energy, in a quest to answer this very question, secured an F-4 Phantom jet to a railroad track and ran into a simulated containment wall at 500 miles per hour – faster than most airline speeds and half as fast as a rifle bullet. The plane completely vaporized. The wall was unharmed. As Ted Rockwell, the venerable nuclear scientist who worked on the Manhattan Project, puts it: “An airplane is essentially a hollow metal tube. It doesn’t make a very good battering ram.” Because the September 11 jets so easily penetrated the glass-and-steel structure of the World Trade Center, people have gotten the idea that a nuclear containment structure is equally vulnerable. It is not.

Ultimately, safety has always been the first principle of the American nuclear industry.

The Dangers of Radiation. Most people don’t know that we are bathed constantly in a sea of low-level radiation. It comes from uranium and thorium in rocks, from radon gas in the atmosphere, from traces of radioactive tritium (heavy hydrogen) in water, from cosmic rays arriving from outer space, and from radioactive carbon and potassium that are absorbed from the air and soil by fruits and vegetables and find their way into our own bodies. Most Americans receive more radiation from bananas than they do from nuclear reactors. If there were “no safe dose of radiation,” every human being would have cancer by age 20.



Only 1/5th of our radiation exposure comes from manmade sources, most of it medical procedures

Normal background exposure is measured in “millirems.” The average American receives 350 millirems each year. Four-fifths of this comes from natural sources and one-fifth from medical procedures, mostly x-rays. The exposures from nuclear reactors are miniscule, even in comparison to background levels. The legal limit for property-line emissions from a nuclear reactor is 1 millirem per year. In comparison, a chest X-ray gives you about 20 millirems in a fraction of a second. So

20 years of living next to a nuclear power plant would give you the same exposure as one chest X-ray.

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People living in the Rocky Mountains receive twice the national average in background radiation because the thinner atmosphere lets in more cosmic rays and because the granite contains more uranium and thorium. They also have the nation's lowest cancer rates. The highest rates are in the Mississippi Delta, where background radiation is ***lowest***. Ultimately, low-level radiation is a natural part of our environment and nuclear reactors add no or negligible amounts to what Mother Nature had already put there. A comprehensive study by the National Academy of Sciences in 1990 found no elevated rates of cancer in communities surrounding nuclear reactors.

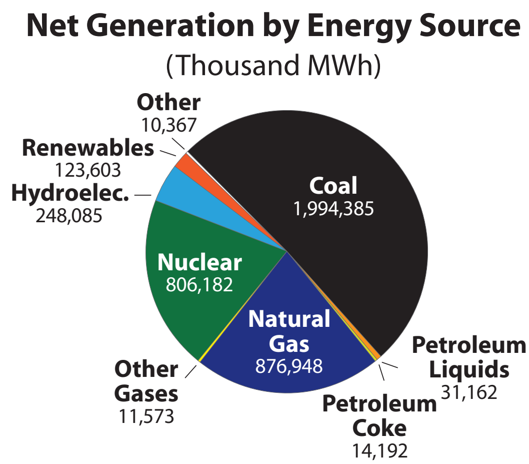
Workers in nuclear reactors, in nuclear shipyards, and crewmembers of nuclear submarines are constantly exposed to 50-to-150 additional millirems per year as part of their work. They have been studied exhaustively for negative health effects and none have ever been found. A study of nuclear shipyard workers sponsored by the Department of Energy found cancer rates well below the general population and lower than similar workers in other industries. The study was never released, on the grounds that it failed to find ***higher*** cancer rates.

Given this information, it is clear that the dangers surrounding nuclear power have been highly exaggerated by the opponents of nuclear power. The health risks are no greater than any other industrial sector and may in fact be less. The federal Occupational Safety and Health Administration (OSHA), for example, has found the nuclear industry to be safer than the "FIRE" sector – finance, insurance and real estate – which consists entirely of white-collar employees in professional offices. As Patrick Moore, the co-founder of Greenpeace who now supports nuclear power, puts it, "I would be happy to live ***in*** a nuclear reactor. It's safer than living outside."

This is why America can double its current fleet of 104 nuclear reactors within the next twenty years without causing any risk to public safety and health.

The Requirements for a 100-Reactor Build-Out of the Nuclear Fleet

Construction. America can build one hundred new reactors by 2030. If conservation efforts can keep electrical consumption from rising significantly, that would mean carbon-free nuclear could provide close to 40 percent of our electricity, up from 20 percent today. Coal could be reduced to 15 percent, which would mean that older plants could be retired and newer ones outfitted with carbon capture and sequestration (which cuts the power output of a coal plant) or some other technology. Natural gas could increase to 27 percent and hydroelectricity to 8 percent. Then if wind, solar and other renewables could be uplifted to 10 percent – not an unreasonable goal – we would have an electrical sector with 30 percent less carbon output than today.

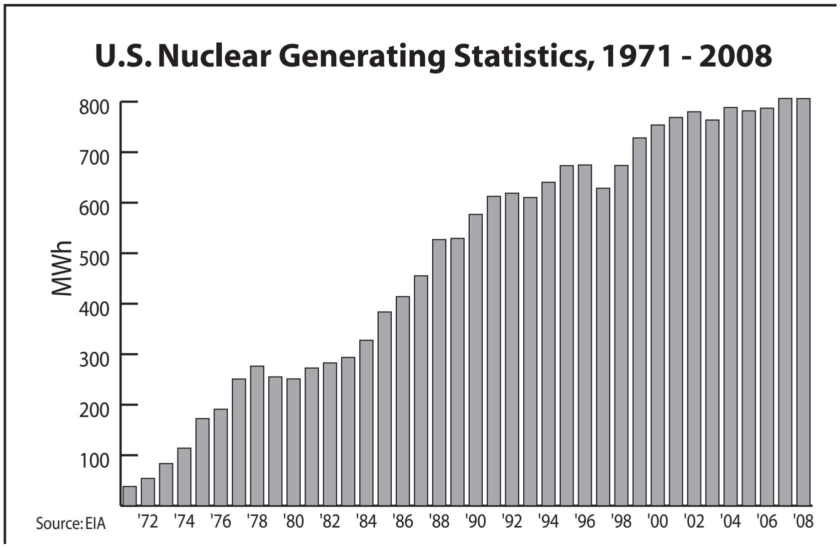


Half of our electricity comes from coal, only 20 percent from nuclear

This should put the United States within the limits of the Kyoto Protocol on global warming.

This should put the United States within the limits of the Kyoto Protocol on global warming. Moreover, it could be accomplished without putting great stress on the environment or handicapping the manufacturing economy. In addition, renewed nuclear construction would lead a revival of American manufacturing, both through the high-tech requirements for construction and through cheaper electricity.

All this will cost a lot of money but it should not be prohibitively expensive. Current high-end estimates are that new reactors may cost $5-to-7 billion apiece (The Tennessee Valley Authority (TVA) just finished reconstructing the abandoned Brown's Ferry 1 Reactor, damaged in a fire in 1976, on schedule and within its $1.8 billion budget.). A price tag in this range would put the cost of 100 new reactors around $700 billion, less than the cost of the American Recovery and Reinvestment Act of 2009 (the stimulus bill). But nearly all the money will come from private investment.



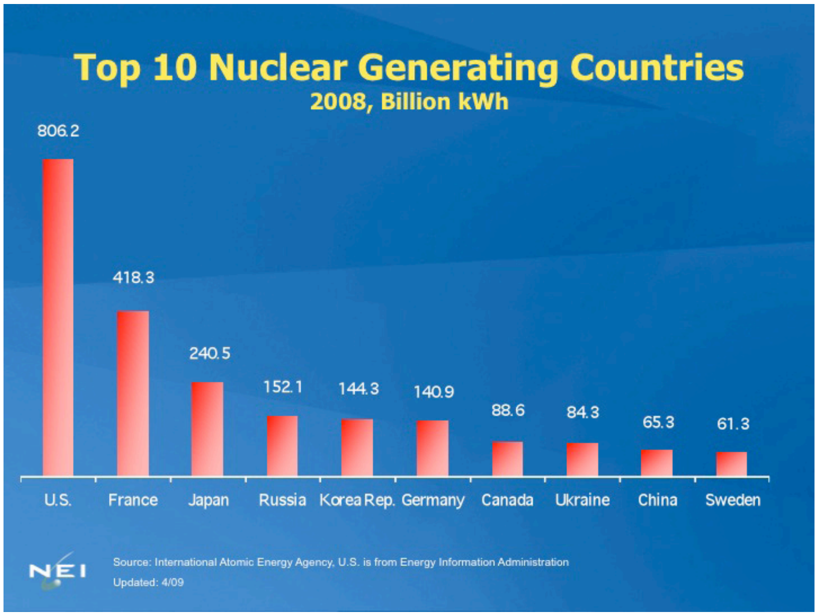
Output form the nation's nuclear fleet has climbed steadily even though we have added only two new reactors since 1990

Many foreign governments and manufacturers are poised to invest in American nuclear construction. The only federal contribution would be loan guarantees for the first dozen-or-so reactors, and loan guarantees are designed to cost the American taxpayer zero dollars. The first four awards, totaling $18.5 billion, were made in June 2009.

With the regulatory uncertainties removed, nuclear power becomes a remarkably attractive investment. Upon completing Brown's Ferry 1 in 2007, Tennessee Valley Authority expected to pay off the construction debt in ten years. After two years of operation, however, the TVA realized it would pay off the debt off in less than three years. With coal prices high and natural gas prices uncertain, and with nuclear fuel locked up in long-term contracts, reactors are now making a profit of close to $2 million a day selling electricity. Once construction debt is paid off, these profits help maintain low rates and keep jobs in the U.S.

It is not as if we have not been through this before. From 1970 to 1990 the nation built 95 reactors, completing fifteen a year at the height of construction. Oyster Creek in New Jersey, the nation's oldest operating reactor, went into service in 1969 and was just relicensed to operate another 20 years. In 1979, when Three Mile Island occurred, there were 150 new reactors on the drawing boards, with most of the sites already chosen. Only 50 of these were ever opened. Building another 100 reactors by 2030 would simply mean going back and finishing the job.

Many lessons have been learned in the meantime. Almost every reactor built in the 1970s and 1980s was one-of-a-kind. Because no two reactors were the same, the industry had no common pool of knowledge and did not communicate on safety. This was one of the flaws that led to Three Mile Island. In the current renaissance, the manufacturers have taken a completely different approach. Each company has concentrated on one standard model – Westinghouse's AP 1000, Areva's EPR, GE-Hitachi's ABWR, and Mitsubishi's USAPWR. The NRC is issuing "design certifications" for these standard models so each utility applicant does not have to start again on square one when

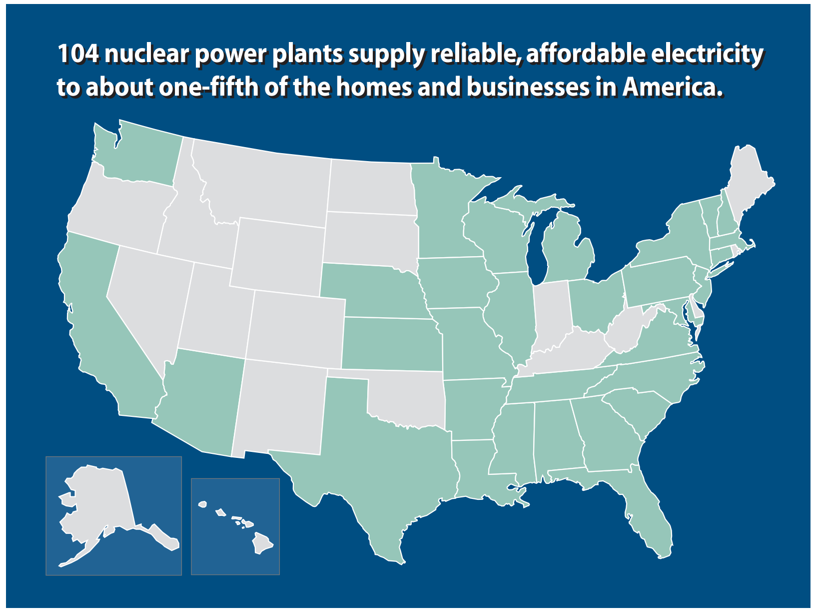


The U.S. still holds the lead in overall nuclear generation

a decision is made to construct a new reactor. Other new models are on the way. In June 2009, Babcock & Wilcox introduced "mPower," a 125-megawatt modular reactor that can be built in a factory and shipped by rail to the construction site like Lego blocks, at a per megawatt cost similar to larger reactors. Modularization will alleviate the "bet-the-company" syndrome, where a utility must invest more than its net worth for new power that may not arrive for another five years. B&W says mPower can be completed in three.

Most important, a 100-reactors-by-2030 effort will mean a rebirth of Industrial America. At present, only one company in the world – Japan Steel Works – is in the business of forging and exporting reactor vessels for commercial plants. Utilities around the world are lined up and there is a four-year waiting list. Russia and China have both just completed new steel forges so they do not have to wait in line in Japan (The Chinese are planning 60 new reactors.). Meanwhile, America's ability to do this kind of work has atrophied. In 1980 we had 150 companies supplying nuclear components. Today there are only 40. If a Nuclear Renaissance is going to take place, investors, manufacturers and skilled workers are going to have to step forward and say, "We can do the job."

Then there are the fields where we have only tentatively ventured. America will probably need four new uranium enrichments plants to supplement the two we are currently building. Then there will have to be a nuclear reprocessing industry. This could be done in conjunction with the industry's future "Generation IV" reactors, which will burn fuel recycled from spent rods. Some steps are already being taken. Areva, the French giant, has announced plans for a uranium enrichment plant in Idaho and a nuclear components factory in Newport News, built in partnership with Northrop Grumman. Areva is also talking about reviving waste reprocessing at the Barnwell plant in South Carolina. Much of the investment money for these projects will obviously come from abroad. NRG, which has received federal loan guarantees for two reactors in Texas, hopes to get one-third of its financing from the Japanese government. Unistar, a partnership between Constellation Energy of Maryland and EDF, the French national electric company, is seeking financing from the French government. In terms of nuclear technology, we have become a slightly underdeveloped country.



More than half the states already have reactors

In a 2008 report, Oxford Economics USA estimated that a nuclear revival in America would produce about 250,000 high-quality manufacturing jobs. Because of the heavy manufacturing involved in nuclear construction, Oxford Economics notes, these jobs will be difficult if not impossible to outsource.

America's nuclear industry has been allowed to wilt on the vine. Dozens of suppliers got out of the business. Tens of thousands of construction workers have been denied high-paying jobs. A whole generation of nuclear engineers and technicians eventually quit the field, tired of trying to explain to friends and relatives how they were not trying to poison the planet or blow up the world. Today it is difficult to find a nuclear engineer under age 55 – although a new generation is starting to emerge from the reviving nuclear engineering schools.

Today a revival is already underway. According to a report in *U.S. News & World Report:*

> *Even without recruiting, some university departments are seeing as much growth as they can handle: There are more than three times as many nuclear engineering students now as there were just five years ago. "Today's students don't have the same fear of nuclear power that their parents did," says Mark Pierson, a professor at Virginia Tech. [Alison Go, "The New Hot Job: Nuclear Engineering," U.S. News & World Report, August 14, 2008.]*

Nuclear engineering schools are experiencing a surge in enrollment as young people sense the opportunity. North American Young Generation in Nuclear, a professional association, has emerged to represent the field. "Young women make up more than a third of our membership," says Lisa Shell-Sikes, who served as president for several terms. South Carolina Senator Lindsey Graham, an enthusiastic supporter of nuclear power, recently helped found a nuclear engineering program at South Carolina State University, the first at a historically black university.

All this does not automatically ensure success. For America to build 100 new reactors by 2030 a lot of things will have to be done right. Most important, the Nuclear Regulatory Commission will have to issue licenses that will stand up in court. Public Citizen, the Naderite Public Interest Research Groups (PIRG), and Greenpeace are all loaded for action, challenging regulatory decisions every step of the way. These groups cannot be taken lightly. PIRG has branches in every major state, fueled by its raid of student activity funds at colleges all over the country. Greenpeace International has an annual budget of $150 million, half again as large as the UN's World Health Organization. All these opposition groups are staffed with skilled lawyers and eager young volunteers anxious to make their mark on the world. Stopping nuclear power has been a near-religious vocation for opposition groups in the past and will be again.

Fortunately, the opposition is concentrated mostly in the Northeast and the West Coast, where not much manufacturing takes place and where opposition extends to all kinds of industrial activities. In the Heartland, people are eager to embrace nuclear power. The people who understand industry and its needs should be allowed to make the decisions for industry. Nothing is more important for manufacturing than cheap and reliable electricity.

<u>*Locations for New Reactors*</u>. Finding locations to put 100 new reactors will not be anywhere near as difficult as it might seem. There is not much of a NIMBY – "not in my backyard" – syndrome with nuclear reactors. Most people that have them love them. Instead, opposition usually comes from national organizations such as Greenpeace, the Sierra Club, and Ralph Nader's Critical Mass, which have an anti-nuclear agenda.

A recent Gallup Poll shows that 59 percent of the public now favors nuclear power – an all-time high [http://www.gallup.com/poll/117025/support-nuclear-energy-inches-new-high.aspx]. This is up from 46 percent in 2001 and an all-time low of 40 percent right after Three Mile Island. Moreover, another poll by Bisconti Research, sponsored by the Nuclear Energy Institute, finds that support rises to ***86 percent among people living within ten miles of a reactor*** ["National Survey of Nuclear Power plant Communities (10-Mile Radius Around the 64 Plant Sites), July-August 2007," Bisconti Research, Inc.]. This is because local people realize that fears of nuclear are wildly exaggerated and that reactors provide tax revenues and good jobs. In the South and Texas, where most of the new reactors are being proposed, support for nuclear is the strongest, in part because of a heavy concentration of Navy veterans who learn the technology in nuclear-powered naval vessels. Meanwhile, the opposition is centered in cities on the East and West Coasts where no new reactors are planned. These areas usually tend to oppose most other forms of energy generation as well, so there is nothing unique about their opposition to nuclear power. The New York City area, for example, has rejected coal plants, natural gas plants, gas pipelines, offshore gas terminals, offshore wind farms, and just about every other form of energy generation, so their opposition to nuclear is not surprising.

There are currently 17 license applications for 28 new plants before the Nuclear Regulatory Commission. That would put us more than one-quarter of the way to 100 new plants. These plants are concentrated heavily in the South and Texas and almost all are at existing reactor sites. Many sites were originally designed as "energy parks" to accommodate three and four reactors. If we were to use what is already available, we could build nearly 100 new nuclear plants without developing many new locations. If smaller modular reactors are licensed, many small towns may want to have one to reduce dependence on the cross-country grid. Once public fears are overcome, developing new locations should not be difficult. The designers of the 1970s who envisioned nuclear as the wave of the future planned well.

The new reactors already seeking licenses before the NRC are as follows:

- Bell Bend Nuclear Power Plant, Luzern County, Pennsylvania.
- Bellefonte Nuclear Station, Units 3 and 4, Tennessee Valley Authority, Jackson County, Alabama.
- Callaway Plant, Unit 2, AmerenUE, Callaway County, Missouri.
- Calvert Cliffs, Unit 3, Calvert Cliffs 3 Nuclear Project, LLC and UniStar Nuclear Operating Services, LLC, Calvert County, Maryland. *(awarded federal loan guarantee)*
- Comanche Peak, Units 3 and 4, Luminant Generation Company, LLC, Somervell County, Texas.
- Fermi, Unit 3, ESBWR Detroit Edison Company, Monroe County, Michigan.
- Grand Gulf, Unit 3, Entergy Operations, Inc. Claiborne County, Mississippi.
- Levy County, Units 1 and 2, AP1000 Progress Energy, Levy County, Florida.

- Nine Mile Point, Unit 3, Nine Mile Point 3 Nuclear Project, LLC and UniStar Nuclear Operating Services, LLC, Oswego, New York.
- North Anna, Unit 3, Dominion, Louisa County, Virginia.
- River Bend Station, Unit 3, Entergy Operations, Inc. St. Francisville, Louisiana.
- Shearon Harris, Units 2 and 3, Progress Energy, Wake County, North Carolina.
- South Texas Project, Units 3 and 4, South Texas Project Nuclear Operating Company, Matagorda County, Texas. *(awarded federal loan guarantee)*
- Victoria County Station, Units 1 and 2, Exelon, Victoria County, Texas.
- Virgil C. Summer, Units 2 and 3, South Carolina Electric & Gas, Fairfield County, South Carolina. *(awarded federal loan guarantee)*
- Vogtle, Units 3 and 4, Southern Nuclear Operating Company, Burke County, Georgia. *(awarded federal loan guarantee)*
- William States Lee III, Units 1 and 2, Duke Energy, Cherokee County, South Carolina.

Since the first reactors cannot reasonably be expected to be completed before 2015, we would have to turn out seven reactors a year after 2018 to meet the 2030 goal. That is not an unreasonable pace. The Nuclear Regulatory Commission considerably simplified the process in the 1990s by introducing the "combined construction and operating license" (COL), which removes the risk of spending $7 billion on a reactor and then not being allowed to start it up. Design certification should also shorten licensing times and lessen the chances of construction delays and cost overruns. All the roadblocks to nuclear power are in the initial stages. Once construction begins, it should accelerate.

<u>Reviving American Industry</u>. In 1990 there were 150 major suppliers for the nuclear industry. Today there are only 40. This trend will have to be reversed. One of the most important aspects of a nuclear revival will be the rebirth of an American steel industry. The most important part of a reactor is the pressure vessel. This is a single steel forging that must withstand immense pressure through the reactor's 40-to-60-year lifespan. No American steel forge is now capable of producing the ultra-heavy forging for the pressure vessel. Japan Steel Works is now backed up four years, and recently invested $2 billion to triple their output. France and Russia have forges for their own reactors and China just completed one in two years to further their plans for building 60 new reactors.


A nuclear containment structure under construction in France

It is hard to believe that America cannot match this performance. But there are potential candidates:

- Chicago Bridge & Iron Co. has won a $150 million engineering, procurement and construction contract from Westinghouse to build the first two containment vessels for AP1000 reactors in the U.S. CB&I previously built 41 reactor pressure vessels and has constructed 75 percent of the concrete-and-steel containment vessels built in this country.

- Open Die Press in North America. The company has expressed interest in upgrading its forge to reactor vessel standards.

Other portions of the revival of the nuclear industry are also underway. In 2008, the Shaw Group and Westinghouse entered a joint venture to build a $100 million Lake Charles, Louisiana facility to produce structural components, piping, and equipment modules for Westinghouse's AP1000. Scheduled to begin operations this year, it will employ up to 1,400 workers. The company has already built a similar plant in China. Areva, the French nuclear giant, has entered a $360 million joint venture with Northrop Grumman to build a nuclear parts factory in Newport News. Scheduled to open in 2011, the facility will also manufacture for export. Alstom is investing $200 million in Chattanooga, Tennessee, in a factory to build the world's largest steam turbines up to 1,800 megawatts.

In 2008, the Edison Welding Institute, one of the largest welding schools in the country, formed the Nuclear Fabricators Consortium in an effort to gear up the construction industry for the coming revival. In particular, specialty welders will be needed. Fifty companies have joined and the Consortium is scheduled to meet again in September 2009.

Enrichment and Reprocessing Facilities. Central to the nuclear chain are enrichment and reprocessing. Enrichment creates reactor-grade fuel by separating the isotopes of uranium. Reprocessing deals with the spent fuel rods: separating the non-fissionable uranium, recycling U-235 and plutonium for fuel, and extracting valuable isotopes for medical and industrial use. Reprocessing largely reduces the problem of "nuclear waste," in terms of both volume and duration.

During the Manhattan Project, American scientists enriched uranium through “gaseous diffusion.” Only one such plant now remains, in Paducah, Kentucky, operated by the United States Enrichment Corporation (USEC), a former government corporation that was privatized in 1996. Gas centrifuges, a more modern technology, were invented in Europe in the 1960s and now provide the continent with most of its fuel. Two centrifuge facilities are under construction in the U.S.: USEC’s plant in Piketon, Ohio and Louisiana Energy Services’ (LES) facility in Lea County, New Mexico. In 2008, Areva applied to build the Eagle Rock Enrichment Facility in Bonneville County, Idaho by 2014 and has already amended its application to double the facility.

American reprocessing has been slower to develop. We are now about twenty years behind France. In the 1970s, private investors were building a facility in Barnwell, South Carolina, scheduled to supply mixed uranium-and-plutonium (MOX) fuel to the Clinch River Breeder Reactor. President Carter cancelled Clinch River in his first months in office, citing concerns about nuclear proliferation. This move set us back. Other countries went right on reprocessing and have gotten far ahead in the technology. Nor has their handling of plutonium led to nuclear proliferation. Rogue countries that desired nuclear weapons didn’t rely on western reprocessing, they instead built their own enrichment plants (Iran) or extracted plutonium from their own reactors (Pakistan, North Korea). It is time to acknowledge our abandonment of reprocessing as a historical mistake.

Once again, Areva is leading the way. The French company is exploring several sites, including Barnwell, to revive an American reprocessing effort. Areva already supplies half of America’s nuclear fuel by “de-enriching” bomb-grade uranium from former Soviet weapons down to reactor grade. One out of every ten light bulbs in America is lit by a former Soviet weapon, an unprecedented effort in turning swords into ploughshares.

It is unnerving to see Russia, China, Japan, and France moving ahead of us so rapidly in nuclear technology. We are in danger of being left behind. The implications for the American economy and our political role in the world would be enormous. As soon as we overcome our misgivings about the technology, however, it is likely we can retake the lead in the world’s peaceful and orderly adoption of nuclear energy.

The Costs of Nuclear Power

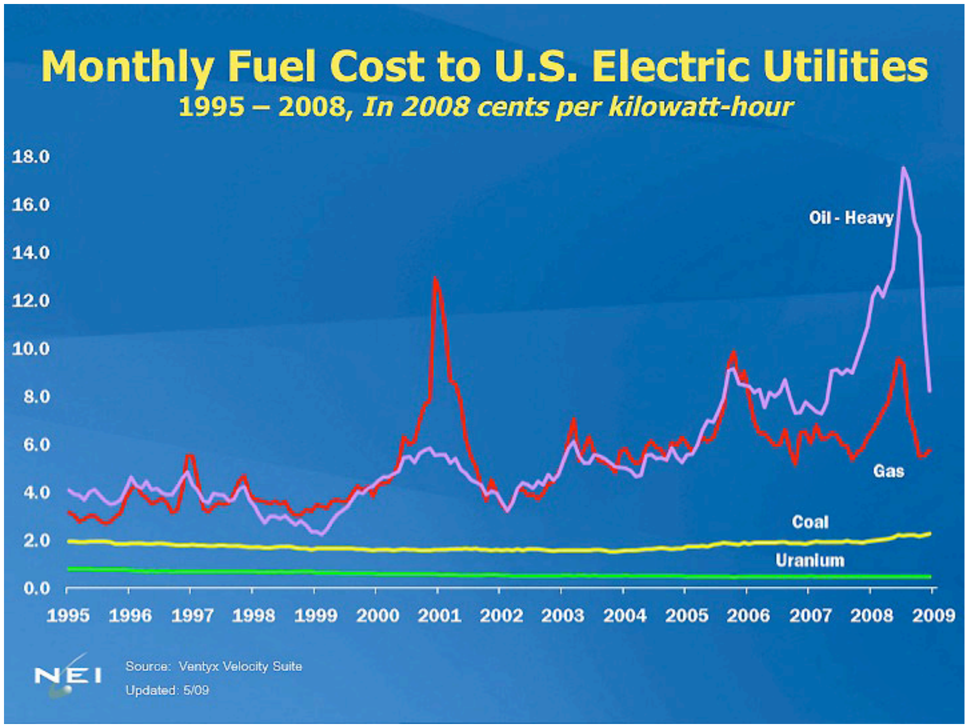
Construction Costs versus Fuel Costs – Nuclear Power's Advantage. Building a new reactor can be a risky undertaking, of that there is no doubt. It is one of the biggest construction projects ever attempted by a private enterprise. But the rewards are worth it. Because of their high performance and low operating costs, the profits, and consequently low electricity rates for consumers, can ultimately be spectacular.

Nuclear power's great disadvantage is that all the costs occur up front. Reactors are now estimated at $5 to $7 billion. But, once these construction costs are paid, reactors can be run very inexpensively because fuel and operating costs are very low. ***The average nuclear reactor in America is now making close to $2 million a day.*** Nuclear power's comparative advantage can only improve as fossil fuel costs rise and the effort to reduce carbon emissions takes shape.

The difference in construction and operating costs between different energy technologies is illustrated in the following table:

	Percent of overall costs	
	Construction	Operating
Natural gas	10	90
Coal	30	70
Nuclear	75	25
Wind	90	10
Solar	90	10

Natural gas turbines are inexpensive to build, but operation is highly dependent on fuel costs which vary widely. Coal plants are more expensive to build than natural gas and still somewhat dependent on fuel prices. Nuclear power's costs are almost all up-front but once the plants are constructed they are insulated from fluctuations in uranium prices. Wind and solar, of course, have no fuel costs and only minimal operating costs, but their construction costs are higher than nuclear power (for equivalent capacity), since such vast complexes are necessary to produce moderate amounts of unreliable electricity.



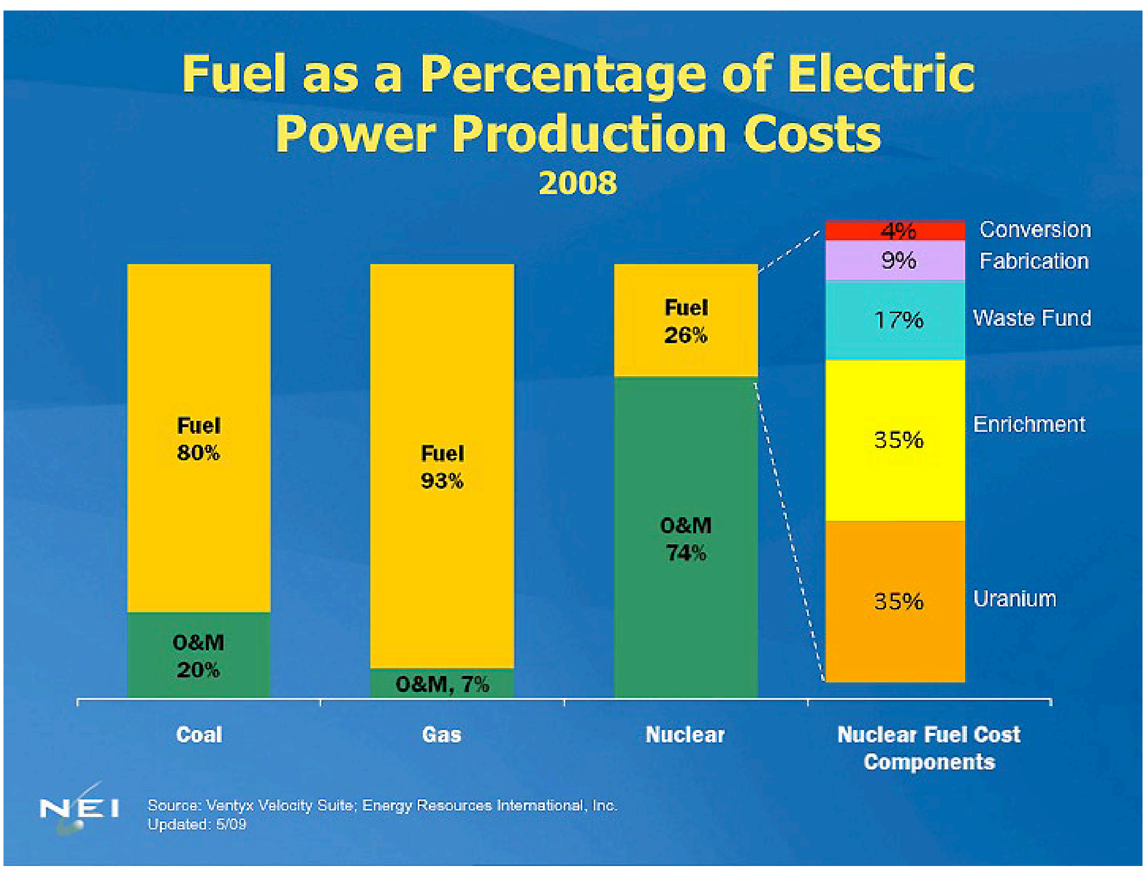
Uranium prices have been extremely stable over the years.

More than 90 percent of the new electricity capacity built since 1990 has been natural gas, since its pollution is relatively low and environmentalists generally do not object to it. But, high fuel costs have prevented wide use of natural gas for baseload power. As a result, natural gas plants have the lowest capacity factor of any means of generation – 20 percent, meaning that they only produce 20 percent of what they could. In other words, they're idle most of the time due to high fuel cost. Wind and solar vary with the weather, and are not available most of the time. Nuclear plants on average are available 90 percent of the time, because reactors now run continuously for nearly two years, and only stop for refueling.

Fuel	Percent of National Capacity	Capacity Factor	Percent of Generation
Coal	50	70	50
Natural gas	39	20	20
Hydro	10	40	8
Nuclear	10	90	19
Renewables	4	30	3

Thus, while reactors cost about twice as much to build as coal plants and three times as much as natural gas turbines, they are nevertheless able to produce competitively cheap electricity. Once they have paid down construction debt and need to meet only operating and fuel costs, they can produce regular profits – and low rates. When oil prices ran up in 2006, Connecticut proposed a windfall profits tax on two nuclear plants – Millstone 2 and 3 – because they were making so much money. No wonder American utilities are eager to build nuclear reactors.

The French experience has shown what a nuclear economy can do for a country. France now has among the lowest per-capita carbon emissions and the lowest electrical rates in Europe. It imports only half as much Russian natural gas as Britain and Germany. Electricity is France's third largest export and French reactors are keeping the lights on in Belgium, Germany and Switzerland. Italy now imports 80 percent of its electricity from France and has decided to revive its own nuclear program. France is luring electricity-intensive industries from other countries, particularly Spain, which jumped into renewable electricity with both feet in 2004 and saw its electrical rates climb 30 percent since. Nuclear power has become the backbone of French prosperity.



Once a nuclear plant is built, its major costs are behind it.

<u>Finding Investment.</u> "Wall Street was willing to invest in subprime mortgages but it still finds nuclear reactors too risky." That's the evaluation of Arjun Makhijani, president of the Institute for Energy and the Environment and a prominent nuclear opponent. That remark seems to hit home. Where will the money come from? Investors are not yet lining up to put their money into nuclear plants. Yet it would be wrong to think that Wall Street is the only potential source of funds. If the federal government were dependent on Wall Street to bankroll its trillion-dollar deficits, we would have been in Chapter 11 years ago.

For the first stages of the Nuclear Renaissance, we will have to draw on the experience of other countries that have gone ahead with the technology while the United States held back. Indeed, we could not build a single reactor today without drawing on some foreign parts. Only one American company – General Electric – still builds reactors and it is working in partnership with Hitachi. Westinghouse Corporation's nuclear operations were bought by Toshiba in 2006. Mitsubishi is also marketing a commercial reactor. Foreign governments are anxious to see their companies succeed and every one of the 26 proposals before the NRC involves some foreign investment.

Wall Street remains wary because it recalls the 1980s, a challenging period for nuclear investing. Plants took as long as 18 years to complete and came in at five times over budget, much of it due to anti-nuclear activist intervention (the very same activists that now point to nuclear as "too expensive"). And acting in response to Three Mile Island, the NRC regularly ordered that completed reactors be torn apart and built over again in order to incorporate new safety features. At one point, in response to opposition lawsuits, the NRC ordered utilities to spend $1 billion per reactor in order to lower the "property-line" emissions from 5 millirems to 1 millirem per year – the same amount of radiation a person would get from taking a single cross-country flight. The experience left Wall Street spooked. No one wants it to be repeated.

The shift to COLs – combined construction and operating licenses – has been a huge advance. This should prevent episodes such as Shoreham, where the Long Island Lighting Company spent $5 billion on a reactor and was then unable to open it because a single governor refused to sign off on an evacuation plan. Even more reassuring to investors is the "regulatory insurance," adopted in the Energy Policy Act of 2005. If a project becomes unreasonably delayed by regulatory procedures or adversarial lawsuits, insurance will cover the losses.

The Energy Policy Act of 2005 also contained $60 billion in loan guarantees to various energy projects but only $18 billion was allocated to nuclear. The Nuclear Energy Institute complains that this will only partly cover four reactors and is asking the coverage be expanded to $100 billion. Nevertheless, $18 billion is a good start. The important thing will be to get the first four or five reactors through the process smoothly. Once the legal issues have been settled and investor confidence established, succeeding projects may not need the same elaborate protection.

The reluctance of Wall Street to take the first step has revived the charge that nuclear has never paid for itself but has always been an industry protected by government subsidies. A look at the record shows that this is not true. In the heady days of the 1970s, America's three reactor manufacturers – General Electric, Westinghouse, and Babcock and Wilcox – practically gave away reactors, absorbing huge losses under the premise that they were carving out market share and ensuring a place in the industry of the future. It is the same impulse that built the railroads, the Internet and any other major infrastructural development. Now there are four competing reactor vendors – GE/Hitachi, Westinghouse, Areva, and Mitsubishi. Once the first hurdles are cleared, competitive forces will likely take hold and companies will once again be willing to take on risk.

Does Nuclear Need Government Subsidies? One of the most frequently used arguments against nuclear power is that it is not economical but simply a creature of government subsidies. One commonly cited statistic is that nuclear energy has received almost $100 billion in subsidies over the decades while renewable energy has received $10 billion. The implication is that without government intervention nuclear power never would have developed in the first place.

There are several flaws to this argument:

1) Nuclear power has been around since the 1940s while serious development of renewable technologies only began in the 1980s. In terms of current subsidies, renewable energy receives far more attention while nuclear power receives almost nothing. In addition, much of the "nuclear subsidies" have actually been spent on nuclear weapons programs.

2) Most federal nuclear spending has concentrated on research. The federal government has always kept a tight hold on nuclear technology, often not allowing private industry

to engage in research without its permission. Even today research into commercial reprocessing is controlled by the government. Much of this spending would have been undertaken by private firms if they had been allowed.

3) While renewable energy has received production tax credits since 1980 – and construction regularly collapses when Congress fails to renew them – nuclear plants have never received subsidies for operation or construction. All 100 plants built between 1970 and 1990 were financed by private enterprise. The 2005 Energy Act finally provided a 1.8 cents per kilowatt-hour production tax credit – the same tax credit that renewables have been getting since 1980 – but it is limited to the first 6,000 megawatts and is only intended to jump-start the renewal. No one is suggesting permanent subsidies for producing nuclear power.

4) Uranium enrichment was performed for the utilities for many years at below cost by government plants that were also serving the weapons program. But these facilities were privatized in the 1990s and enrichment is now done on a market basis.

5) When measured by its actual output, renewables receive about ten times more government support than other sources. This may be because renewables are still in the early stage of their development. However nuclear did not receive the same subsidies at such an early stage.

In 2006, the Nuclear Energy Institute sponsored a study that compared the subsidies to all forms of energy generation, including ***tax incentives*** as well as direct expenditures on research. The study found that over the 20th century, the largest federal subsidy was the oil depletion allowance granted to oil production as a temporary measure during World War I and never rescinded until the 1970s. Natural gas production was hugely subsidized by federal price controls and laws requiring producers to meet demand at low costs. Nearly all hydroelectric dams are built and operated by some government entity and sell electricity to the public at below-market prices. Renewables are not only subsidized by large tax credits but are also being mandated by renewable portfolio standards adopted by more than half the states. No one has ever mandated that utilities build nuclear reactors.

If we applied the same insurance arguments to bank accounts that anti-nuclear activists apply to the nuclear industry, then a bank would be too risky a place to put your money. Obviously, that's not the case.

Price-Anderson Insurance. Perhaps the most common misconception is that nuclear power is "uninsurable" and that were it not for the special protection and huge federal subsidies in the Price-Anderson Act, so the argument goes, commercial nuclear technology never could have existed. This is confused and inaccurate on many points:

1) Nuclear was "uninsurable" in the 1950s only because there was no actuarial record for nuclear plants, as required by state laws. European companies that traditionally insured untried technologies in America had not recovered from World War II.

2) Having the federal government act as an "insurer of last resort" is hardly unusual. The Federal Deposit Insurance Corporation protects the banking system. The Pension Benefit Guaranty Corporation insures corporate pensions. Even your house could not be insured against floods without federal backing. The ***Catalogue of Federal Insurance Activities,*** the General Accounting Office's listing of all actions insured by the federal government, is 90 pages long. If we applied the same insurance arguments to bank accounts that anti-nuclear activists apply to the nuclear industry, then a bank would be too risky a place to put your money. Obviously, that's not the case.

3) The forfeiture of the right to contest damages in exchange for a liability cap, as set up by Price-Anderson, is also nothing unusual. Worker's Compensation works the same way. Factory owners trade their right to contest damage suits for a limit to their liability for industrial accidents. Without Worker's Compensation, every American factory would be "uninsurable" because of unlimited exposure to workplace accidents.

4) Although the federal government originally assumed responsibility for all damages in excess of $500 million, no compensation was ever paid. The claims against Three Mile Island amounted to only $71 million. In any case, Price-Anderson has long since changed. The current system now organizes private insurance companies into

providing the first $300 million in coverage. After that, ***each operating reactor can then be assessed up to $100 million to cover further damages.*** With 104 operating reactors, this means overall protection to the public is ***$10 billion per accident.*** No other industry has anything approaching this kind of coverage.

5) Price-Anderson has never cost the federal government a dime. It is simply a bill that establishes a property-rights regimen in which the nuclear and insurance industries can operate. Rather than a “subsidy,” this is simply a function of good government.

The myth that nuclear power would not exist except for government subsidies and protection is entirely false. Nuclear power is a robust technology that is perfectly capable of supporting itself. The barriers to further expansion of our nuclear infrastructure are political, not economic.

Reprocessing and Nuclear Waste

<u>*The Composition of Spent Fuel Rods*</u>. When questions about safety and cost are put to rest, the question always remains, "What are you going to do with the waste?" Several states, including California, have passed laws saying that no new reactors can be built until a permanent solution is found. The difficulty now seems even more intractable since the Obama Administration has said it will not continue with the geological repository at Yucca Mountain.

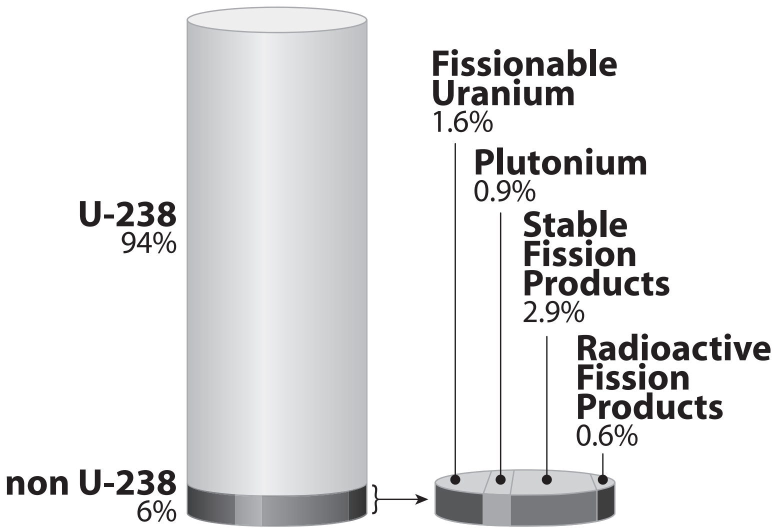
Yet the whole question is premised wrong. More than 97 percent of the material in a spent fuel rod can be successfully recycled. After sitting in a reactor for five years, only 3 percent of a fuel rod's potential energy has been tapped.

It is important to remember the incredible density of nuclear energy. All the spent fuel rods that are removed from American reactors during the course of a year take up less space than a house. All the spent fuel that has ever been generated in the U.S. would cover one football field to a height of 21 feet. And this is ***before*** any reprocessing. Recycling procedures generally reduce the volume of material by 70 percent, and that includes the disposal container.

All the spent fuel rods that are removed from American reactors during the course of a year take up less space than a small house.

Ninety-six percent of a fuel rod is uranium-238, the non-fissionable isotope. Basically, it is there for packing material. It serves no purpose except to hold the fissionable isotope, U-235. The natural uranium is only mildly radioactive and poses no danger; it can be handled safely with gloves. For regulatory purposes, however, it has been classified as "low-level waste." This means it can be safely disposed by burying it in the ground.

Processing of Used Nuclear Fuel



94 percent of a spent fuel rod is non-fissionable uranium. Most of the remaining 6 percent can be recycled.

Enriched uranium is 4 percent U-235, as opposed to 0.7 percent in the natural ore. After for five years in a reactor, U-235 is back down to ~ 1 percent. This 1% can be recycled. Meanwhile, about 1 percent of the U-238 has been transmuted into plutonium, which is also fissionable. But plutonium can be blended with U-235 to form MOX fuel, which can be used as fuel in most reactors. This means both the uranium and plutonium "waste" can be recycled for energy, as the French are doing at their fuel fabrication plant in Avignon.

The remaining 3 percent is fission products and actinides (radioactive elements heavier than uranium) that are produced in the reactor. These are highly radioactive and must be handled remotely. But many are also valuable medical and industrial isotopes. ***Nuclear medicine is an $8 billion industry.*** It is a prime technology in treating cancer. Yet we import 100 percent of our medical isotopes (those from reactors, not cyclotrons) from Canada because we do not recycle our own nuclear materials. We are neglecting an important commercial resource.

The problem in dealing with spent fuel rods, of course, is their intense radioactivity. They are intensely radioactive. However, six feet of water or four feet of lead can block all radiation. There has been no incident anywhere in the world where a person has been injured or killed by exposure to spent fuel.

"Nuclear waste" is not a flaw in nuclear technology. The real problem with used nuclear fuel is that we gave up reprocessing in the 1970s. We have wrestled with the consequences ever since.

At this point, there are two options we can take for reprocessing: an approach similar to that of the French, British, and Japanese, where most of the spent fuel is recycled for use in current-

The real problem with used nuclear fuel is that we gave up reprocessing in the 1970s. We have wrestled with the consequences ever since.

generation light water reactors, or a more advanced approach where almost the entire spent fuel is recycled for use in advanced Generation IV reactors. The Generation IV approach yields less final waste with a shorter lifespan, but will require about 10 years of solid work to finalize engineering and build a demonstration plant. Either approach can be used to deal with the current stockpile of spent fuel.

Nuclear proliferation. The decision to end nuclear reprocessing in the U.S. was driven by the concern that isolating plutonium in American reprocessing plants would lead to the proliferation of nuclear weapons. India had just built a bomb in 1974 from plutonium extracted from a Canadian-supplied research reactor, so there was some reason for concern. John McPhee's bestseller, ***The Curve of Binding Energy,*** helped popularize the idea that reprocessing and proliferation were two sides of the same coin.

This attempt to "lead by example" was spectacularly unsuccessful. The French, British, Russians, and Japanese went right on reprocessing and have made significant advances in the technology. At the same time, history has shown that if nuclear weapons are going to proliferate, stealing plutonium from reprocessing operations will not be the likely route. Nuclear technology is no longer a secret and most countries have their own scientists.

North Korea has built a nuclear weapon by extracting plutonium from a reactor built on a British design that was originally published as part of the "Atoms for Peace" program. Dr. A.Q. Kahn, the "father of Pakistan's nuclear program," ran a clandestine ring of international proliferation, selling both technology and nuclear material to China, Iraq, and North Korea. Iran and Iraq have pursued uranium enrichment. None of it had anything to do with stealing American plutonium. The French have reprocessed for twenty years and none of their efforts has led to nuclear proliferation.

For all these reasons, we should immediately start a revival of nuclear reprocessing in this country. The effort will both relieve any need for the Yucca Mountain facility and permanently resolve the problem of nuclear waste.

Climate Legislation


The carbon dioxide we emit each year may be affecting the climate.

Cap and Trade. At present, it appears possible that some form of carbon legislation is going to make it through Congress this year. An economy-wide cap-and-trade system on greenhouse-gas emissions would be a huge burden on the American economy and would mean allowing the government to intrude even further into the energy marketplace. What is even more objectionable is the "renewable portfolio standard" that would throw all market mechanisms aside and simply dictate to utilities that they must build "renewable" generating stations whether needed or not.

Let it be noted that, under a properly designed system, nuclear power would one of the greatest beneficiaries of a regime to limit carbon emissions. Nuclear's great advantage over coal is that is has zero carbon emissions. It also has zero sulfur, nitrogen, and mercury emissions. A properly designed tax on carbon or cap-and-trade system would raise the costs of all fossil fuels and make nuclear power a clearer choice – even with its significant up-front costs. The price of building a coal plant with complete carbon sequestration would probably exceed the cost of a nuclear reactor – although no one really knows because it has never been done.

Renewable Portfolios. Democrats in Congress are not satisfied with just cap and trade. Instead of leveling the playing field, they have decided to tilt it decisively toward certain means of generation – specifically those that are deemed "renewable and sustainable." The Waxman-Markey bill, as currently written, would mandate that American utility companies get 12-15 percent of their electricity from renewable energy – a highly speculative undertaking since renewables only constitute about 3 percent of our current electrical generation. Achieving this goal is much less likely than building 100 new reactors by 2030 because (1) we have already built 100 reactors and know how to do it again, and (2) the environmental problems of covering vast areas of mountains and deserts with renewable generating facilities and then pumping the electricity across hundreds or even thousands of miles have not yet been confronted.

The uncertain definition of what is "renewable and sustainable" has also set off confusion and logrolling in Congress that is almost comic. Large hydroelectric plants, which are our greatest source of renewable energy, have not been classified as renewable because environmental groups have been opposing them since the 1950s. In fact the big effort now is to tear dams down. Meanwhile, burning wood wastes, municipal garbage, crops, and even trees has been designated as "renewable." How is this supposed to reduce carbon emissions? In becoming involved in the pursuit of "renewable and sustainable" energy, Congress has lost sight of its original purpose – to reduce carbon emissions.

Is Nuclear Power Renewable? By any reasonable definition, nuclear power is both renewable and sustainable. Uranium is about as common as tin. Estimates are that the world holds several hundred years' supply of uranium and can sustain a large upturn in use. Beyond that is thorium, the other naturally radioactive element, which is twice as abundant as uranium and is also readily usable in nuclear reactors. India has the world's largest known supplies of thorium and is building its energy economy around thorium reactors.

Finally, there is the aforementioned Generation IV nuclear technology, in which the far more abundant U-238 isotope is transmuted into plutonium in large quantities, forming an almost unlimited supply of nuclear fuel. Cycling uranium through a reactor only once uses only 3 percent of its potential energy. With the introduction of a Gen IV cycle, we will be on the road to using the entire energy value and almost completely eliminating any problem of nuclear waste. All this is still 25 years in the future, but we could start exploring the technology now – as France and Japan are already doing – by funding an experimental Gen IV reactor.

Rather than saddling the economy with a carbon tax – which could be the largest tax in history – we should take a pro-active approach to climate change and start building nuclear reactors. Instead of stagnation and an uncertain future built around dubious forms of energy generation, we will be firmly on the road to clean, cheap energy, a revival of American industry and technology, and a healthy and prosperous economy.

Nuclear's environmental footprint consists of little more than its cooling towers.

Conclusion

<u>*The Inconvenient Solution*</u>. Anyone surveying the entire world with its growing populations reaching for greater prosperity cannot doubt that nuclear power is the energy source of the future. As American Nobel Prize winner Glenn Seaborg, who discovered plutonium, put it in 1956, "Nuclear power has come along just at the right time because we are reaching the limits of fossil fuels."

We first struck up against those limits when America's domestic oil production peaked in 1970. From being the world's largest exporter of oil we have gone to being the world's largest importer in a few short decades. America has never been the same. The anxiety of being dependent on foreign fuel sources and entangled with the unstable regimes of the Middle East preys on us still today. Reviving nuclear power will not end our foreign oil dependence. It is not even the beginning of the end. But it is the end of the beginning. If we are ever to transfer sizable portions of our transportation sector to electric vehicles – which seems to be the most promising strategy – we will need much larger quantities of solid, stable reliable energy that is there regardless of the time of day or the weather. We can't have Americans going to bed every night praying for a strong wind so they can drive their cars in the morning.

The second limitation to fossil fuels we have since encountered is climate change. It is difficult to judge the severity of the crisis, but we do believe the problem is serious enough that it is worth taking steps in the right direction. If global warming is the inconvenient problem, nuclear power is the inconvenient solution.

It is time to see America lead the world again in technology. It is frightening to see China and Russia charging ahead with nuclear power, setting up their own steel forges, selling their technology to Brazil and Venezuela, while America lingers behind. If the vast populations of China and Asia and Africa cling to coal burning, then nothing we do in the United States will have much impact on global warming. But if they forge ahead with nuclear power, we had better be in the lead. Otherwise we will find them rapidly surpassing us in every aspect of modern industrial and technological production.

For all these reasons and more, building 100 new reactors by 2030 is not only a necessity in dealing with global warming but a grand opportunity to revive America's economy. We led the world in pioneering nuclear technology in the 20th century. We should be leading the world in taking advantage of it in the 21st.

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