KEVIN PETERSEN
STATE REPRESENTATIVE

Testimony on AB 384 – Lifting Wisconsin's Nuclear Moratorium and Adding Advanced Nuclear Energy to State Energy Policy

According to United States Department of Energy, "The USA has 100 nuclear power reactors in 31 states, operated by 30 different power companies. Since 2001 these plants have achieved an average capacity factor of over 90%, generating up to 807 billion kWh per year and accounting for 20% of total electricity generated." Despite being only 1/5 of the nation's energy, nuclear power accounts for 72% of the country's carbon dioxide emission-free generation.

Three sites are located in Wisconsin. The LaCrosse reactor in Genoa was permanently shut down in 1987. Kewaunee's reactor was shut down in May, 2014. Point Beach's two reactors have operational licenses expiring in 2030 and 2033.

AB 384 repeals the provisions of 1983 ACT 401 known as Wisconsin's Nuclear Moratorium. According to the analysis by the non-partisan Legislative Reference Bureau; "Under current law, with certain exceptions, a person may not construct any new power plant unless the Public Service Commission has issued a certificate to the person. The PSC may not issue a certificate unless specified requirements are satisfied. In addition, if the proposed power plant is a nuclear power plant, current law prohibits the PSC from issuing a certificate unless the PSC finds both of the following: 1) that there is a facility with sufficient capacity to receive the spent fuel from all nuclear power plants in the state; and 2) that construction of the power plant is economically advantageous to ratepayers based on specified factors."

A provision of the Nuclear Waste Policy Act of 1982 required the federal government construct a national repository for storing spent nuclear fuel at Yucca Mountain in Nevada. In 1983 when Wisconsin's nuclear moratorium was imposed, technology did not exist to store spent nuclear fuel in any other manner except by warehousing it offsite.

On March 3, 2010, the Department of Energy filed a motion with the Nuclear Regulatory Commission to withdraw the license application for a high-level nuclear waste repository at Yucca Mountain with prejudice. President Obama's fiscal year 2011

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budget request eliminated funding for the Office of Civilian Radioactive Waste Management.

Over 30 years have resulted in major technological advances in nuclear storage. Yucca Mountain is no longer needed. Instead, facilities can deposit their spent fuel in dry cask storage. According to the United States Nuclear Regulatory Commission; "Dry cask storage allows spent fuel that has already been cooled in the spent fuel pool for at least one year to be surrounded by inert gas inside a container called a cask. The casks are typically steel cylinders that are either welded or bolted closed. The steel cylinder provides a leak-tight confinement of the spent fuel. Each cylinder is surrounded by additional steel, concrete, or other material to provide radiation shielding to workers and members of the public. Some of the cask designs can be used for both storage and transportation."

On August 26, 2014 the Obama Administration's Nuclear Regulatory Commission (NRC) issued a final rule on continued spent nuclear fuel storage. The Waste Confidence Decision was revised to the "Continued Storage of Spent Nuclear Fuel Rule."

The continued storage rule adopts the findings of the Generic Environmental Impact Statement (GEIS) regarding the environmental impacts of storing spent fuel at any reactor site after the reactor's licensed period of operations. As a result, those generic impacts do not need to be re-analyzed in the environmental reviews for individual licenses. The GEIS analyzes the environmental impact of storing spent fuel beyond the licensed operating life of reactors over three timeframes: for 60 years (short term), 100 years after the short-term scenario (long term) and indefinitely.

The next step for used fuel could very well be something other than putting it in dry cask storage. It is not "nuclear waste" unless we decide to waste it. The potential usable energy represented by spent fuel rods makes a compelling case for advanced nuclear energy technologies which can convert waste into fuel. Generation IV reactors using molten salt designs will be using what is currently considered nuclear waste as there fuel source.

Additionally, AB 384 incorporates advanced nuclear energy options into state energy policy using a reactor design, or amended reactor design approved after December 31, 2010, by the United States Nuclear Regulatory Commission. Advanced nuclear energy will be prioritized between combustible renewable energy resources and nonrenewable combustible energy resources.

Any nuclear-electric proposal site will still be subject to all of the limitations the Public Service Commission imposes when analyzing any new power generating facility.

The bill does not contemplate nuclear will displace any of the statutorily prioritized resources, such as energy efficiency and conservation, or renewable energy. If those sources can cost effectively and suitably supply Wisconsin's energy needs, then no nuclear plant would need to be built.

At the same time, if analyses prove nuclear energy is overly cost prohibitive, and sufficient renewables are not available, the bill still allows utilities to build or refurbish gas or other fossil fuel power plants.

Last year, the Department of Energy announced public – private research in advanced nuclear reactors in a press release titled Energy Department Announces New Investments in Advanced Nuclear Power Reactors;

"This type of public-private research in advanced nuclear reactors will help accelerate American leadership in the next generation of nuclear energy technologies, and move the United States closer to a low carbon future, "said Energy Secretary Ernest Moniz. "These types of investments are crucial to the continuing role of nuclear power as a significant contributor to the U.S. energy economy."

Our state has one of the nation's leading nuclear power programs at the University of Wisconsin - Madison. In the last 5 years the program has received multiple grants totaling approximately $16 million and is working on next generation nuclear in concert with other research powerhouses such as MIT. The proposed legislation allows advanced nuclear energy to be considered along with other energy options sending the signal Wisconsin is ready to expand its energy portfolio and reach for the future

Coal and nuclear are dependable sources of fuel for "base" load electricity. "Base" load electricity is the electricity needed 24 hours per day, 7 days per week, 365 days per year to power homes and businesses.

In other words, if the wind isn't blowing on a hot summer day, a windmill will not provide electricity to your air conditioner. Nor will solar panels produce the needed energy to heat your house on a gray winter day.

Recently, the federal Environmental Protection Agency issued global warming regulations on coal-fired power plants. Between 2012 and 2030, Wisconsin will have to reduce its carbon emissions by approximately 34%. According to the Milwaukee Journal Sentinel, the cut would be the sixth-highest in the country.

Modifying fossil fuel burning electric power plants will be extremely expensive, ranging from $3.4 billion to $13.4 billion, according to estimates from state utility regulators. Those costs will be passed on to Wisconsin families and businesses.

Middle class jobs in Wisconsin will be jeopardized. While most of the country's economy has switched from manufacturing to service and consumer driven sectors, Wisconsin's biggest employer remains manufacturing. In order to compete globally as well as domestically, Wisconsin businesses must have access to energy that is both affordable and reliable.

It is time to lift the moratorium; advanced nuclear energy is a clean, safe, and affordable way to meet future energy demands in Wisconsin, the Unites States, and around the world. It emits virtually no greenhouse gases (GHG), making it a clean power source.

AB-384 simply reopens the door to a technology that has advance well beyond what it was when or state closed that door 30+ years ago.

Statement of Alex Flint
Senior Vice President, Governmental Affairs
Nuclear Energy Institute
November 18, 2015

Mr. Chairman. I am Alex Flint, representing the Nuclear Energy Institute. I'm here this morning representing 350 companies in 17 countries that build, own and operate nuclear power plants.

Perhaps it's more relevant for today's hearing that before I got my current job, I spent several decades involved in the development of energy policy. One of the things I've become convinced of over those years is that long-term energy predictions tend to make fools of those who make them.

To my way of thinking, there is a cycle to energy policy decisions. We begin by reaching consensus on changes, we enact new federal laws like we did in 1992 or 2005, and state and federal regulatory authorities begin rulemakings that eventually result in new regulations. Just when we begin to experience both the intended and unintended consequences of those new laws, they get challenged in courts with varying results, a mess ensues, and then, slowly, another consensus begins to develop and another law results.

Add to that occasional, massive market changes. In the nuclear business, when the Cold War ended and the United States began buying up huge amounts of uranium from Russian nuclear warheads and using it as fuel in our reactors to produce electricity, we saw uranium prices drop to 10 percent of what they had been during the 1980s.

Today, natural gas is transforming the electricity and manufacturing industry in ways we never predicted a decade ago. In fact, the 2005 Energy Policy Act on which I worked included key provisions to accelerate the construction of natural gas import facilities – we were worried about shortages – and now we are racing to build natural gas export facilities.

I expect we will see several more cycles of laws and regulations and changing markets over the next several decades.

Mr. Chairman, I begin with this acceptance of uncertainty because I'm not here today to tell you that a new nuclear reactor should ever be built in Wisconsin – I simply don't know. I don't know what future electricity markets will be like. I don't know the impact of the U.S. Environmental Protection Agency's Clean Power Plan or whatever comes after it. And I don't know what nuclear technology will be available in any particular year.

There are challenges associated with building and operating nuclear power plants. Just to mention one, I know Wisconsin has long been frustrated by the federal government's failure to fulfill its obligations under the Nuclear Waste Policy Act. I'm as frustrated as any of you may be, and would be glad to share my thoughts on that in response to questions if you have any.

But we must keep in mind that nuclear energy is unique in its ability to produce large-scale, carbon-free electricity around the clock. When a nuclear power plant is refueled, it runs at 100 percent capacity, 24 hours a days for 18 to 24 months until it needs refueling again, when it goes offline for somewhere around 25 days. Collectively, America's nuclear reactors produce electricity about 90 percent of the time. They operate whether or not the wind is blowing and the sun is shining, and whether or not fuel arrives by truck, barge, rail or pipeline.

Each plant produces a massive amount of electricity. Assuming Wisconsin electricity per capita use, a 1,000 MW nuclear plant would produce enough power for 945,000 homes in Wisconsin – with a relatively small footprint.

For those concerned about greenhouse gas emissions and/or clean air, America's nuclear power plants produce 63 percent of the nation's carbon-free electricity. The two Point Beach reactors on Lake Michigan account for 72 percent of Wisconsin's zero-emissions generation. No other industrial construction project compares to building a new reactor – at peak construction, each one employs about 3,500 people. Five new reactors are under construction in three states: Georgia (Vogtle 3 and 4), South Carolina (Summer 2 and 3) and Tennessee (Watts Bar 2). Together, these projects employ more than 7,000 workers and are among the largest construction projects in these states.

Nuclear plants also provide long-lasting economic benefits once operational. An average nuclear plant employs between 500-700 people, paying salaries that are over 30 percent higher than average salaries in the local area. The average nuclear plant pays around $16 million annually in state and local taxes, adding benefits to local schools, roads and other infrastructure. Each year the average nuclear plant generates approximately $470 million in economic value.

And the United States is good at operating nuclear power plants. Almost a quarter of the world's commercial reactors are in the United States, and 60 percent of the world's 438 operating reactors are based on U.S. technology. We have the world's most respected regulator and our plants are recognized for reliability, safety and operational excellence.

Looking to the future, the nuclear industry is developing a pipeline of new technologies that includes small modular reactors and advanced reactor designs. These new technologies have the potential to enhance the nuclear technology options available to utilities building new generation. Small modular reactor developers are working with the NRC on design certification applications and over 30 organizations have plans for advanced fission reactor designs. Some advanced reactor designs are being marketed to consume used fuel or provide process heat for large industrial uses. And with all that, a new nuclear power plant may never make good sense for Wisconsin – but one might.

It may be that, one day, the economy in Wisconsin will grow and the state will need more electricity. It may be that future regulations will make importing electricity from other states undesirable. It may be that future regulations will drive up prices or reduce the availability of fossil fuels. It may simply be that, like South Carolina and Georgia, Wisconsin could decide it wants to balance its generating portfolio with more non-emitting advanced nuclear energy technology as a hedge against uncertainty.

Whatever the future might be, my recommendation is that Wisconsin should empower itself with all options as it considers its future. More options are better than fewer options. One of those options should be advanced nuclear energy. Nuclear has its plusses and minuses – consider them all, but do allow yourself to consider them.

November 18, 2015
Assembly Energy and Utilities Committee
Testimony of Frank Jablonski

I am Frank Jablonski. I have been intermittently, and am now, a lobbyist for the Nuclear Energy Institute. Some of you may know me from before. I was also the lead author of a document sponsored by RENEW Wisconsin and the predecessor organization to Clean Wisconsin in 1995. It was called The Green Plan, and posited that we could move forward quickly toward a clean energy economy by relying strictly on efficiency, conservation and renewable energy. I still believe that we should implement energy efficiency and conservation, and use renewable energy wherever it fits in. I no longer believe it is likely to be anywhere near adequate against the scale of energy needs, environmental imperatives, and

I came to this perspective after re-studying nuclear in the early 2000's. I did so for about two years. Intensive investigation of the things I thought I knew about nuclear energy entirely changed my view. I became a nuclear energy advocate. Here are a few of the things I learned as I made the journey from nuclear opponent to nuclear advocate:

- Radiation is a completely natural element of our environment, and it is everywhere. Background radiation exposure for the United State's, averaged, is about 310-320 millirems per year, with about a similar amount added from medical procedures, on average. There is a region in Iran, called Ramsar, where background exposures are 13,000 to 26,000 millirem, without discerned adverse health effects. This is more than designated "hotspots" in Fukushma province.

- There are other high natural background radiation areas throughout the world. Some of them, such as hot springs in Germany, which is noted for its societal antipathy to nuclear energy, and for its new coal plants and high carbon emissions, attract people seeking what they believe to be medical benefits, and they even specify a "therapeutic dose." Coal plants emit to the ambient environment about 100 times as much radiation as nuclear plants producing the same amount of electricity. This amount is still so low as to be unconnected to adverse health impacts.

There are a lot of environmental issues that merit worry about a lot of things, but radiation is not one of them.

- France replaced fossil fuels almost entirely over a period of about 13 years because of a planned nuclear build-out. Nuclear has scaled up to displace emitting sources of energy faster than any renewable energy options.

- Spent nuclear fuel still holds about 95% of the energy value of fissionable materials. Next generation nuclear reactors, under development now in the United States, and around the world, will be able to convert to days nuclear waste into tomorrow's clean electricity. The resulting residue will degrade to background levels similar to the ore from which the fuel was taken, in 200 to 500 years.

- This forward energy potential of nuclear power bears on one of the talking points, often asserted by people who oppose nuclear energy, is the notion that nuclear is mature technology with no path forward for significant innovation. The worldwide programs of research and development that demonstrate this to be false.

- If we decide to bury spent fuel, we can be confident that it will remain isolated form the biosphere. Natural nuclear reactors operated in Africa for hundreds of thousands of years as life was evolving on this planet. The resulting residues have moved about 10 feet in the ensuing billion + years.

- If we decide to just keep spent fuel around in dry casks, hopefully pending the commercialization of even better nuclear technology options, the NRC has concluded we can safely do so indefinitely. There is no nuclear waste crisis. There is a crisis of scientific ignorance.

I will stop there with my written testimony, in anticipation of time limits. I could go on for a good long time about this technology, and the broad scientific consensus that supports its use, further deployment and further development.

It is time for our state to allow nuclear into the mix if it fits. This is what the legislation permits. I urge you to pass it. I urge that you pass it as an environmental measure.

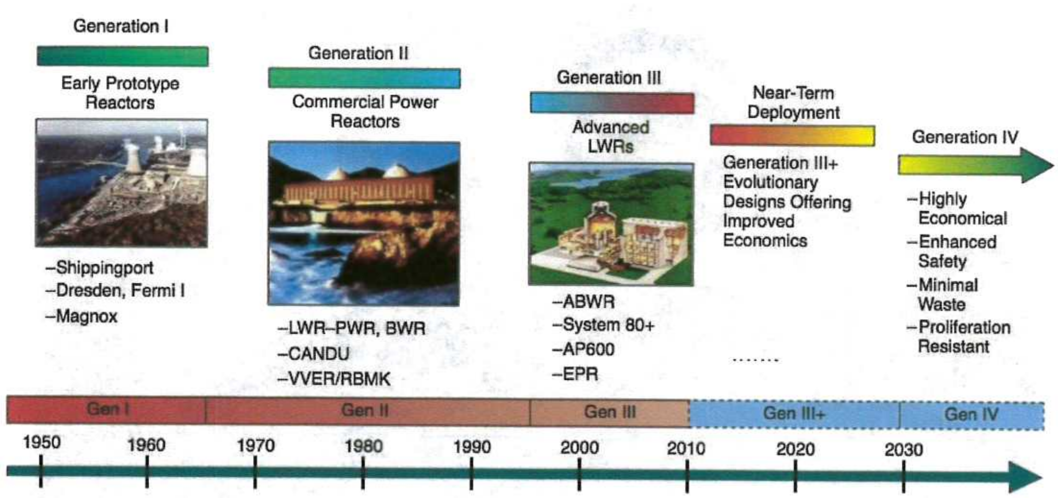
Testimony before the Assembly Committee on Energy and Utilities
November ~~October~~ 18, 2015 (Louis Chapdelaine)

Thank you for the opportunity to testify today. I am an engineering graduate student in Nuclear Engineering. My research focuses on advanced reactors, specifically on molten salt reactor design. I came to the University of Wisconsin program to work on this advanced reactor design after graduating from the University of Illinois, Champaign-Urbana.

I am in favor of Assembly bill 384 and its companion bill in the Senate, and would like to provide Committee members some information on Generation III+ reactors. These are reactor designs currently available in the United States.

First, however, you should know that nuclear energy is a young, fast-evolving energy technology; it is less than 75 years since the first human-controlled sustained reaction was engineered in a former squash court at the University of Chicago in 1942. The graphic in my written testimony is from the Department of Energy, and it summarizes the history of, and current advances being made in, nuclear power technology.

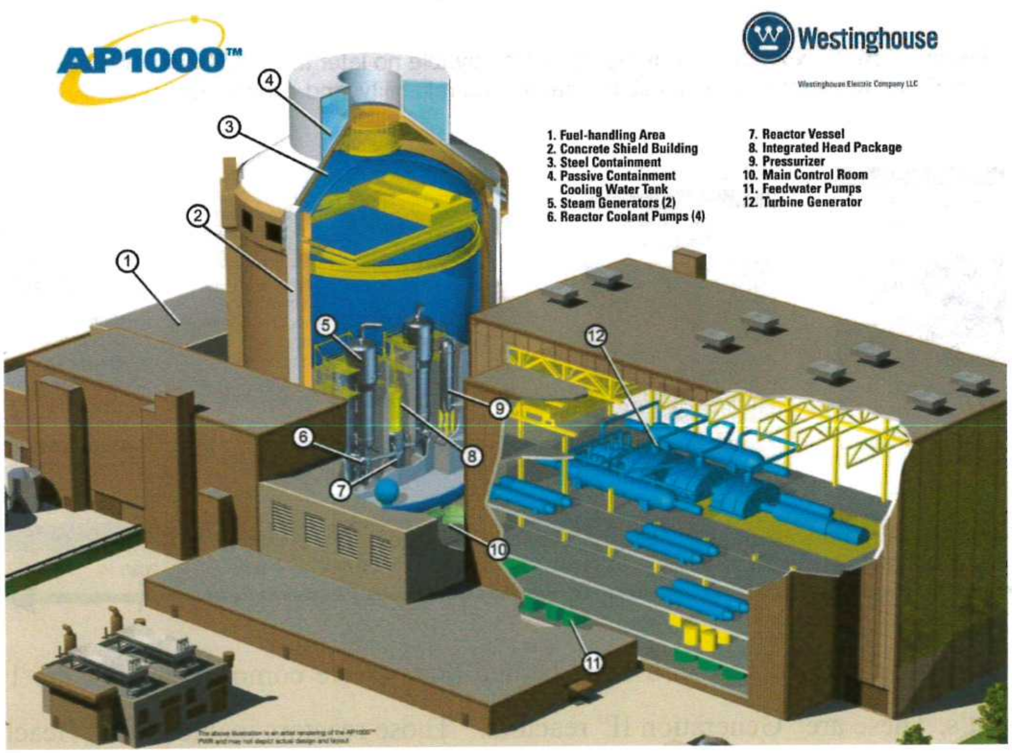
Generation IV: Nuclear Energy Systems Deployable no later than 2030 and offering significant advances in sustainability, safety and reliability, and economics



Most reactors now operating across the United States were commissioned in the 1970's and 1980's. These are "Generation II" reactors. Those reactors include Point Beach, and had included the Kewaunee plant. All Generation II and III reactors approved by the US Nuclear Regulatory Commission use light water as the primary coolant to run the energy cycle. The two major types of reactors that use light water are pressurized water reactors and boiling water reactors.

While Generation II nuclear reactors of western design already represent the safest energy technology ever developed by human beings, we have now moved into Generation III+. These reactors meet strict safety criteria that make them many times safer, more than an order of magnitude, than Generation II reactors.

Regulators describe the Generation III+ AP-1000 reactor design, under construction at four U.S. locations, as "advanced passive." This reflects that the reactor is designed to respond to extreme conditions, such as those that developed at Fukushima, by shutting down and cooling down by relying on the laws of physics. Natural conditions and processes, such as gravity and convection provide an extra level of protection. The graphic in my testimony illustrates the design from Westinghouse, highlighting major components of the plant.



The NRC requires Generation III+ reactors to be three day walk-away safe for design-basis accidents. This means that, in a worst-case scenario, the built in safety systems can keep the facility from melting down or releasing significant amounts of radiation for three days.

More than 60 Generation III+ and Generation IV reactors, of various designs, are now under construction across the world. Four AP-1000s are under construction currently in the US. Two are being built at the Vogtle location in Georgia, and they are to begin generating power in 2019 and 2020 respectively. Two other reactors are being built at the VC Summer location in South Carolina. They are to be commissioned in 2019 and 2020.

In short, Generation III+ reactor designs are even safer than their predecessors, and should be considered an important option for future carbon emission-free energy needs in Wisconsin. I will give an electronic copy of my testimony to the committee chair, where you can read more about what I have said. Thank you for your attention, I will be happy to answer any questions I can pertaining to Generation III+ reactors.

Written Testimony of Dr. Paul Wilson (3909 St Clair St, Madison,WI, 53711) to the Assembly Committee on Energy and Utilities regarding AB 384.

November 18, 2015

Thank you Mr. Chairman, and to the whole committee, for the opportunity to speak in favor of AB 384.

I am a professor of nuclear engineering and the interim chair of the Energy Analysis and Policy graduate certificate at the UW-Madison, and a member of the American Nuclear Society. However, today I am speaking on my own behalf: a father of two teenage girls, and a resident of Wisconsin with an interest in progressive energy policy and environmental ethics.

Energy, and specifically electricty, has been shown repeatedly to be an important driver of economic growth. But our energy sector, especially in Wisconsin, has also been an important cause of environmental degradation, with lasting impacts on the quality of our air and waterways thanks to the emission of pollutants such as mercury, sulfur oxides, nitrogen oxides, particulates and carbon dioxide. Fortunately, we know how to reduce those environmental impacts. We can use less: there are many opportunities for conservation and energy efficiency that continue to support our economic success. We can also use "better"; by switching to electricity generation sources that do not emit harmful pollutants to the environment.

There are obstacles to making this switch, mostly often economic ones. In such cases, we sometimes rely on government to enact policies that can help us make the "right" choice even when it's not the cheapest option. For this reason we have seen production tax credits, loan guarantees and renewable portfolio standards, all with the goal of adding low emission sources to our electricity system.

Unfortunately, in Wisconsin, we have exactly the opposite policies for the single largest source of low emission electricity – nuclear energy. Nuclear energy provides over 60% of the low emission electricity in the United States and it does so with a reliability that is unmatched by any other technology. Nevertheless, Wisconsin's current policy places additional obstacles on nuclear energy making it even harder to deploy the best tool we have for reducing the emissions in our electricity system.

Enacting this legislation is an important step to rectifying this by removing what is purely a policy obstacle and placing nuclear energy. And this legislation does little more than that: it doesn't create specific financial incentives and doesn't make it eligible to be counted in renewable portfolio standards. It continues to place it at a lower priority than renewable energy sources.

This legislation will repeal two specific provisions. One simply states an economic requirement that is essentially a standard part of decision making by the Public Service Commission anyway. The other focuses on the long term storage of used nuclear fuel. Used nuclear fuel is compact, contained and cared for. How is it compact? If your lifetime supply of electricy came only from nuclear energy, your share of the used nuclear fuel would be one soda can. All of the used nuclear fuel ever generated in the US would fit in Camp Randall to a height of about 15 feet. How is it contained? It is a solid – no leaking or oozing – that is contained in multiple layers of metal and concrete. How is it cared for? We, the ratepayers, have been paying for the ultimate disposal of spent nuclear fuel for over 30 years - it's basically the used nuclear fuel version of a carbon tax, but one that actually pays for the long term disposal. We have been handling used nuclear fuel safely and tracking the exact location of all of it, all while developing very sensitive technology to detect the radiation it emits. The irony of the current policy is that in its effect, for approximately 30 years the State of Wisconsin has provided an incentive for the emission of airborne pollutants from fossil fuels instead of the generation of small quantities of carefully tracked used nuclear fuel.

Research being conducted within our nuclear engineering program at UW-Madison looks to further reduce the burden of used fuel disposal. My own research is studying the benefits of used fuel recycling that may one day reduce your lifetime waste volume from a beer can to a shot glass, while also reducing the need to mine new uranium. Others are developing new reactor technologies that would allow some of that recycled material to be consumed in a nuclear reactor to produce additional electricity.

Repealing the current statutes will not result in a new nuclear power plant in Wisconsin any time soon. There are still many other factors that must be considered when selecting new electricity generation sources. But this legislation will allow both utilities and the PSC to realistically consider the role that nuclear energy can play in their future energy mix, and specifically the role that it can play in reducing its environmental impact. For these reasons, I support AB 384.

Preamble

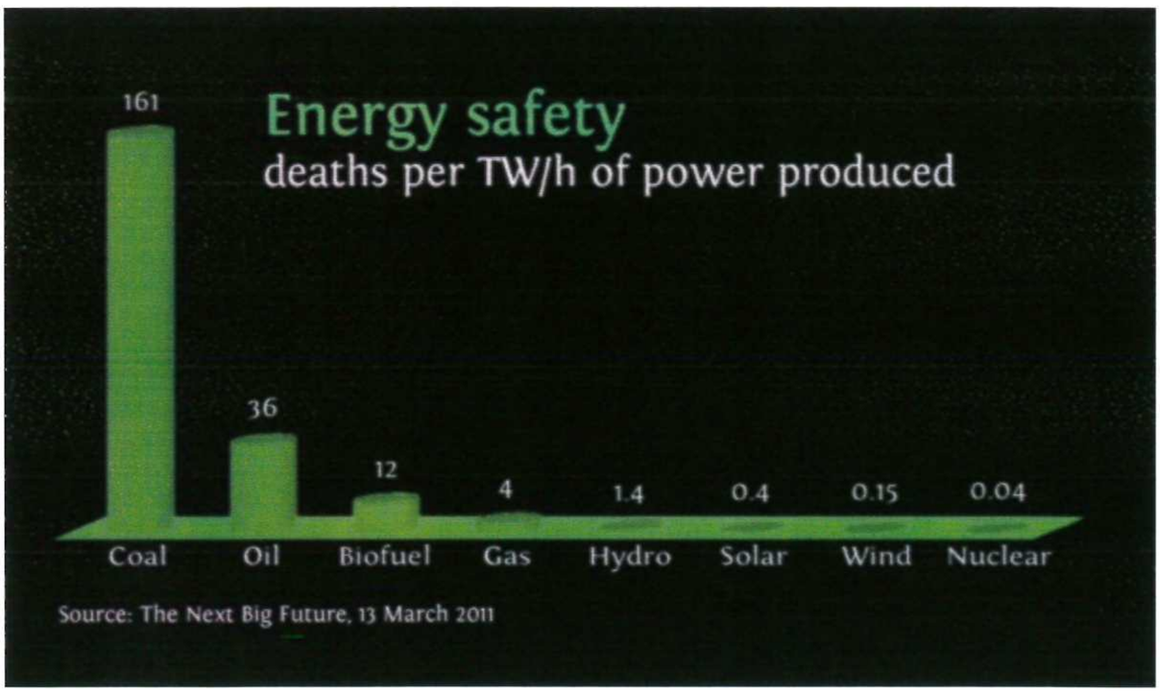
This testimony is from Richard Steeves, MD, PhD, Madison, WI.
My PhD is in Medical Biophysics from the University of Toronto.

I chaired the Section of Radiation Oncology at the University of Wisconsin School of Medicine for 5 years, and I continue at this University as Emeritus Professor.

I have also been leading a PLATO discussion group on "Pathways to a Sustainable Planet" for the past 5 years, where we have explored in depth the role of nuclear energy to reduce carbon emissions in our electric grid.

My testimony today is given on my own behalf and I do not represent any organization. I hope that my views expressed here may serve in the interests of people who are vulnerable to the harms that will develop if Wisconsin continues to burn coal and natural gas for most of our electricity.

If nuclear energy is disallowed from contributing to our future energy needs, Wisconsin will be turning its back on carbon-free energy, which also has the safest track record of all.



Reverse the Moratorium on Nuclear Plant Construction in WI

The rationale for the current moratorium on future nuclear plant construction is based upon the public's fear of the unchecked accumulation of nuclear ***waste***.

But what is this WASTE that we keep hearing about? A careful look into its chemistry reveals that it is simply unused uranium fuel that has the capacity to generate vast amounts of energy in a future generation of compact reactors.

This is because commercial light water reactors that have been built in USA for the past 60 years consume only 2 or 3% of the potential energy in the fuel itself. Every 18 months each one of our current reactors has to be temporarily shut down to remove its unused fuel, which is then stored on-site for later burial.

This was viewed as a negative after the Yucca Mountain storage site was closed, but it can now be viewed as a positive, since advanced reactors can consume vast amounts of the potential fuel that remains conveniently located for use.

Why should we reconsider nuclear energy for the future? It is by far the most efficient way to generate energy that does not pollute our atmosphere with "greenhouse" (planet-warming) gases (CO_2 & methane). The amount of energy released by the fission of one uranium atom is **2 million times** that released from the oxidation of a molecule of coal or crude oil.

Wisconsin lags far behind our neighboring state to the south (Illinois), which generates 90% of its carbon emission-free energy from nuclear plants. We must improve our electric grid support with better choices than coal or natural gas.

The general public seems to be unaware that new reactors are much smaller than our aging behemoths with huge cooling towers that we see on TV. New plants, rigorously designed and tested over the past 30 years, can be assembled on site from mass-produced components. Once fueled, they will operate underground without maintenance for 50 years. Some of them can be fueled by thorium, which is much more plentiful than uranium. We need to rethink our media-driven, irrational anti-nuclear prejudice, and learn to appreciate the potential benefits of nuclear energy.

By Richard Steeves, MD, PhD, Madison, WI

My name is Margi Kindig. I am a retired attorney, served as a citizen member of Governor Doyle's Task Force on Global Warning, and was on the board of a prominent environmental organization for several years.

I have been an environmentalist for my entire adult life, which as you can see is quite a long time! For most of that time I was opposed to nuclear power because I considered it to be dangerous. Born and raised in Manitowoc, I worried about the Point Beach and Kewaunee nuclear power plants and supported those who opposed their construction.

But I am here today to urge you to support this bill.

The reason for my change of heart can be summarized in one word: science. As a practicing attorney I had little interest in science until I began to read about climate change, first in the popular press and, later, in more sophisticated publications. Parenthetically, I also happened to marry someone with a PhD in microbiology who challenged some of my long (and strongly!) held beliefs.

I learned about the Intergovernmental Panel on Climate Change, the National Academies of Science, and consensus science generally.
And what I learned is that my position on nuclear power was not supported by science but was an ideologically-driven position which parroted many of the organizations on which I had until then depended for my information.

I would like to point out just a few of the misconceptions I held about nuclear power.

For example, I always thought Three Mile Island was quite a dangerous accident with grave consequences. In fact, there was only a tiny amount of radiation released at Three Mile Island, and no adverse health effects in the surrounding population. Repeated studies found a small statistically non-significant increase in the rate of cancer in the area around Three Mile Island but no causal connection between those cancers and the accident.
Nevertheless, there are still many people – well-educated, widely read and intelligent people – who talk about deformed babies and deaths from cancer as a result of Three Mile Island.

But Chernobyl seemed (and still does seem to many) almost apocalyptic – thousands, tens of thousands, maybe hundreds of thousands killed; many, many more poisoned and dead from cancer later on; deformed babies; an entire ecosystem destroyed for generations, perhaps forever.

Chernobyl was without a doubt the worst nuclear accident the world has ever seen, but its effects have been grossly exaggerated. Perhaps 50 people died as a direct result of the radiation, including less than 20 deaths from thyroid cancer. In addition, there were approximately 6000 cases of thyroid cancer in children that were successfully treated.

By the time of the Fukushima earthquake and tsunami, I had learned how ill-informed I had been about the dangers of nuclear power and the consequences of both Three Mile Island and Chernobyl. I also knew that the same un-founded fears about the dangers of radiation that followed Three Mile Island and Chernobyl would plague discussions about what happened at Fukushima.

And, indeed, that has happened. Attempts to have reasoned discussions about the benefits of nuclear power are often shut down with the simple question, "But what about Fukushima?" As though that should end the conversation.

In fact there has now – maybe – been one death attributed to radiation exposure as a result of the Fukushima disaster. It is now widely recognized that the greatest public health impacts of Fukushima were a result of *fear* of radiation, not radiation itself.

But don't believe me. Go to the best sources of science that exist and read for yourself. Go to UNSCEAR (the United Nations Scientific Committee on the Effects of Atomic Radiation); our own National Acadamies of Science (probably the best source of science in the U.S.); and the World Health Organization.

My reason for supporting this bill is that I am convinced the world needs more nuclear power to avoid the worst impacts of climate change. There are those who argue that we can achieve the necessary emission reductions by investing more heavily in conservation and efficiency – clearly the low-hanging fruit – and renewables such as wind, solar and hydropower.

But the best sources of science do not support that optimism. Here I would refer you to a joint report from the National Academy of Sciences, the National Academy of Engineering and the National Research Council called "America's Energy Future". You can read it for free online.

There is not time to address another issue often raised by opponents of nuclear power, namely the waste. But again, the science does not support the level of fear stoked by nuclear power opponents.

If you want an excellent summary of the science behind what I have said today, written for the lay person, I highly recommend Nuclear 2.0, Why a Green Future Needs Nuclear Power, by Mark Lynas. It is the best summary of all of these issues I have seen.

The bottom line is that policy should be driven by evidence, not ideology – and certainly not by unfounded fear. Before you vote on this bill, please take the time to look at the science. Look at the reports from UNSCEAR, the WHO, and our own National Academies.

Thank you.

Testimony before the Assembly Committee on Energy and Utilities November 18, 2015, Kelsey Amundson

Hello, my name is Kelsey Amundson and I grew up in Ashwaubenon, Wisconsin. I am a senior in nuclear engineering at the University of Wisconsin – Madison with certificates in Mathematics and Nuclear Engineering Materials. I am also the current American Nuclear Society University of Wisconsin – Madison Student Section President, and I am here representing myself.

My purpose for being here is to discuss why Assembly Bill 384 should be passed. Wisconsin is known for its pristine lakes and forests; and as a state we want to preserve our natural beauty.

One component of Wisconsin's natural beauty is the fresh air, which is currently being polluted through the use of fossil fuels. Over 70% of Wisconsin's electricity generation is from the burning of fossil fuels, including coal and natural gas [1]. A typical coal plant will emit 3.5 million tons of CO2 per year in addition to other harmful gases and particulates [2]. These emissions can lead to serious health effects, such as asthma and even death. In a study conducted by the World Health Organization concluded there were 3.7 million deaths globally due to outdoor air pollution in 2012 [3].

James Hansen, the NASA scientist who began forcefully raising the issue of potential climate change in the late 1980's has studied how nuclear power protects health and saves lives. Included in my testimony is a graphic drawn from one of his recently published peer-reviewed papers [4]:

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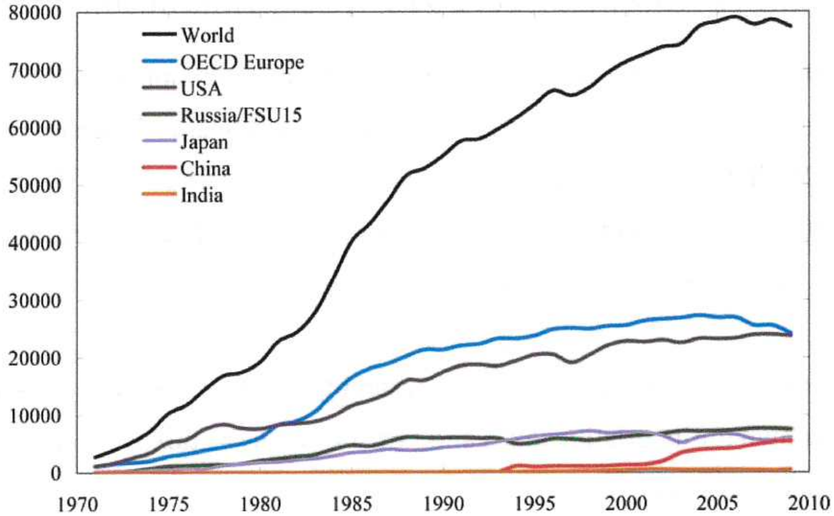
1 *Nuclear Energy in Wisconsin*. Washington, DC: Nuclear Energy Institute, 2014. Print.

2 "Coal Power: Air Pollution." *Union of Concerned Scientists*. N.p., n.d. Web. 17 Nov. 2015.

3 *Burden of Disease from Ambient Air Pollution for 2012*. Rep. World Health Organization, 2014. Web. 17 Nov. 2015.

4 Kharecha, Pushker A., and James E. Hansen. "Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power." *Environmental Science & Technology* (2013): 4889-895. American Chemical Society. Web. 17 Nov. 2015.

Mean number of deaths prevented annually by nuclear power
1971-2009



If we want to improve our air quality while meeting our electrical needs, we need nuclear power. It accounts for nearly two-thirds of carbon-free electricity in the United States [5], and is the only carbon-free electricity source that we know for certain can be implemented on a large scale here in Wisconsin.

Compared to other industries, nuclear power is the only industry that takes full responsibility for the waste that is produced, which is in a solid form. Therefore nuclear waste is easier to manage and is small compared to other energy forms. To put this in perspective, if all of the electricity one-person uses over their lifetime came from nuclear power the total amount of waste would be about the size of a soda can [6].

The Wisconsin legislature should vote to pass this piece of legislation in order to improve our air quality and to minimize our impact on the environment. Thank you.

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Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power

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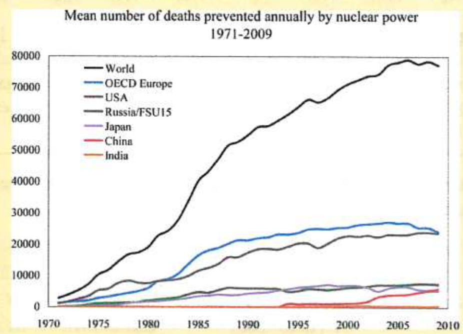
Supporting Information

ABSTRACT: In the aftermath of the March 2011 accident at Japan's Fukushima Daiichi nuclear power plant, the future contribution of nuclear power to the global energy supply has become somewhat uncertain. Because nuclear power is an abundant, low-carbon source of base-load power, it could make a large contribution to mitigation of global climate change and air pollution. Using historical production data, we calculate that global nuclear power has prevented an average of 1.84 million air pollution-related deaths and 64 gigatonnes of CO_2-equivalent ($GtCO_2$-eq) greenhouse gas (GHG) emissions that would have resulted from fossil fuel burning. On the basis of global projection data that take into account the effects of the Fukushima accident, we find that nuclear power could additionally prevent an average of 420 000−7.04 million deaths and 80−240 $GtCO_2$-eq emissions due to fossil fuels by midcentury, depending on which fuel it replaces. By contrast, we assess that large-scale expansion of unconstrained natural gas use would not mitigate the climate problem and would cause far more deaths than expansion of nuclear power.



■ INTRODUCTION

It has become increasingly clear that impacts of unchecked anthropogenic climate change due to greenhouse gas (GHG) emissions from burning of fossil fuels could be catastrophic for both human society and natural ecosystems (in ref 1, see Figures SPM.2 and 4.4) and that the key time frame for mitigating the climate crisis is the next decade or so.[2,3] Likewise, during the past decade, outdoor air pollution due largely to fossil fuel burning is estimated to have caused over 1 million deaths annually worldwide.[4] Nuclear energy (and other low-carbon/carbon-free energy sources) could help to mitigate both of these major problems.[5]

The future of global nuclear power will depend largely on choices made by major energy-using countries in the next decade or so.[6] While most of the highly nuclear-dependent countries have affirmed their plans to continue development of nuclear power after the Fukushima accident, several have announced that they will either temporarily suspend plans for new plants or completely phase out existing plants.[2] Serious questions remain about safety, proliferation, and disposal of radioactive waste, which we have discussed in some detail elsewhere.[7]

Here, we examine the historical and potential future role of nuclear power with respect to prevention of air pollution-related mortality as well as GHG emissions on multiple spatial scales. Previous studies have quantified global-scale avoided GHG emissions due to nuclear power (e.g., refs 5 and 8−10); however, the issue of avoided human deaths remains largely unexplored. We focus on the world as a whole, OECD Europe, and the five countries with the highest annual CO_2 emissions in the last several years. In order, these top five CO_2 emitters are China, the United States, India, Russia, and Japan, accounting for 56% of global emissions from 2009 to 2011.[11] To estimate historically prevented deaths and GHG emissions, we start with data for global annual electricity generation by energy source from 1971 to 2009 (Figure 1). We then apply mortality and GHG emissions factors, defined respectively as deaths and emissions per unit electric energy generated, for relevant electricity sources (Table 1). For the projection period 2010−2050, we base our estimates on recent (post-Fukushima) nuclear power trajectories given by the UN International Atomic Energy Agency (IAEA).[6]

■ METHODS

Calculation of Prevented Mortality and GHG Impacts. For the historical period 1971−2009, we assume that all nuclear power supply in a given country and year would instead have been delivered by fossil fuels (specifically coal and natural gas), given their worldwide dominance and the very small contribution of nonhydro renewables to world electricity thus far (Figure 1). There are of course numerous complications involved in trying to design such a replacement scenario (e.g., evolving technological and socioeconomic conditions), and the

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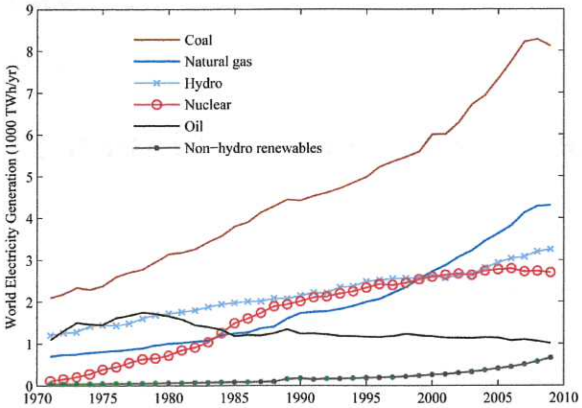

Figure 1. World electricity generation by power source for 1971–2009 (data from ref 14). In the past decade (2000–2009), nuclear power provided an average 15% of world generation; coal, gas, and oil provided 40%, 20%, and 6%, respectively; and renewables provided 16% (hydropower) and 2% (nonhydro).

Table 1. Mortality and GHG Emission Factors Used in This Study[a]

electricity source	mean value (range)	unit[b]	source
coal	28.67 (7.15–114)	deaths/TWh	ref 16
	77 (19.25–308)	deaths/TWh	ref 16 (China)[c]
	1045 (909–1182)	tCO_2-eq/GWh	ref 30
natural gas	2.821 (0.7–11.2)	deaths/TWh	ref 16
	602 (386–818)	tCO_2-eq/GWh	ref 30
nuclear	0.074 (range not given)	deaths/TWh	ref 16
	65 (10–130)[d]	tCO_2-eq/GWh	ref 34

[a]Mortality factors are based on analysis for Europe (except as indicated) and represent the sum of accidental deaths and air pollution-related effects in Table 2 of ref 16. They reflect impacts from all stages of the fuel cycle, including fuel extraction, transport, transformation, waste disposal, and electricity transport. Their ranges are 95% confidence intervals and represent deviation from the mean by a factor of ~4. Mortality factor for coal is the mean of the factors for lignite and coal in ref 16. Mean values for emission factors are the midpoints of the ranges given in the sources. Water pollution is also a significant impact but is not factored into these values. Additional uncertainties and limitations inherent in these factors are discussed in the text. [b]TWh = terawatt hour; GWh = gigawatt hour; tCO_2-eq = tonnes of CO_2-equivalent emissions. [c]Range is not given in source for China, but for consistency with other factors, it is assumed to be 4 times lower and higher than the mean. [d]Some authors contend the upper limit is significantly higher, but their conclusions are based on dubious assumptions.[35]

retroactive energy mix cannot be known with total accuracy and realism; thus, simplifying yet tenable assumptions are necessary and justified.

To determine the proportional substitution by coal and gas in our baseline historical scenario, we first examine the world nuclear reactor properties provided by IAEA.[12] On the basis of typical international values for coal and gas capacity factors (CFs),[13] we then assume that each of the 441 reactors listed in Table 14 of ref 12 with a CF of greater than 65% is replaced by coal and each reactor with a CF of less than or equal to 65% is replaced by gas.

For each country x, we first calculate $P_i(x)$, the power (*not* energy) generated by each reactor i:

$$P_i(x) = CF_i(x) \times C_i(x) \quad (1)$$

where CF_i and C_i denote the reactor capacity factor and net capacity, respectively, listed in Table 14 of ref 12. We then calculate $f_i(x)$, the CF-weighted proportion of generated power by each reactor:

$$f_i(x) = P_i(x) / \sum_i P_i(x) \quad (2)$$

Next, we calculate $F_j(x)$, the total proportion of generated nuclear power replaced by power from fossil fuel j:

$$F_j(x) = \sum_i f_i^{(j)}(x) \quad (3)$$

where $f_i^{(j)}(x)$ simply denotes grouping of all the f_i values by replacement fuel j. For reference, on the global scale, this yields about 95% replacement by coal and 5% by gas in our baseline historical scenario, which we suggest is plausible for the reasons given in the Results and Discussion section. Lastly, we calculate $I(x, t)$, the annual net prevented impacts (mortality or GHG emissions) from nuclear power in country x and year t as follows:

$$I(x, t) = \Sigma_j[IF_j \times F_j(x) \times n(x, t)] - IF_n \times n(x, t) \quad (4)$$

where IF_j is the impact factor for fossil fuel j (from Table 1), $n(x, t)$ is the nuclear power generation (in energy units; from refs 6 and 14), and IF_n is the impact factor for nuclear power (from Table 1). Note that the first term in eq 4 reflects gross avoided impacts, while the second reflects direct impacts of nuclear power.

For the projection period 2010–2050, using eq 4, we calculate human deaths and GHG emissions that could result if all projected nuclear power production is canceled and again replaced only by fossil fuels. Of course, some or most of this hypothetically canceled nuclear power could be replaced by power from renewables, which have generally similar impact factors as nuclear (e.g., see Figure 2 of ref 7). Thus, our results for the projection period should ultimately be viewed as upper limits on potentially prevented impacts from future nuclear power.

We project annual nuclear power production in the regions containing the top five CO_2-emitting countries and Western Europe based on the regional decadal projections in Table 4 of ref 6, which we linearly interpolate to an annual scale. To set $F_j(x)$ in eq 4, we consider two simplified cases for both the global and regional scales. In the first ("all coal"), $F_j(x)$ is fixed at 100% coal, and in the second ("all gas"), it is fixed at 100% gas. This approach yields the full range of potentially prevented impacts from future nuclear power. It is taken here because of the lack of country-specific projections in ref 6 as well as the large uncertainty in determining which fossil fuel(s) could replace *future* nuclear power, given recent trends in electricity production (Figure 1, Figure S3 [Supporting Information], and ref 14).

Methodological Limitations. The projections for nuclear power by IAEA[6] assume essentially no climate-change mitigation measures in the low-end case and aggressive mitigation measures in the high-end case. It is unclear which path the world will follow; however, these IAEA projections *do* take into account the effects of the Fukushima accident. It seems that, except possibly for Japan, the top five CO_2-emitting countries are not planning a phase-down of pre-Fukushima plans for future nuclear power. For instance, China, India, and

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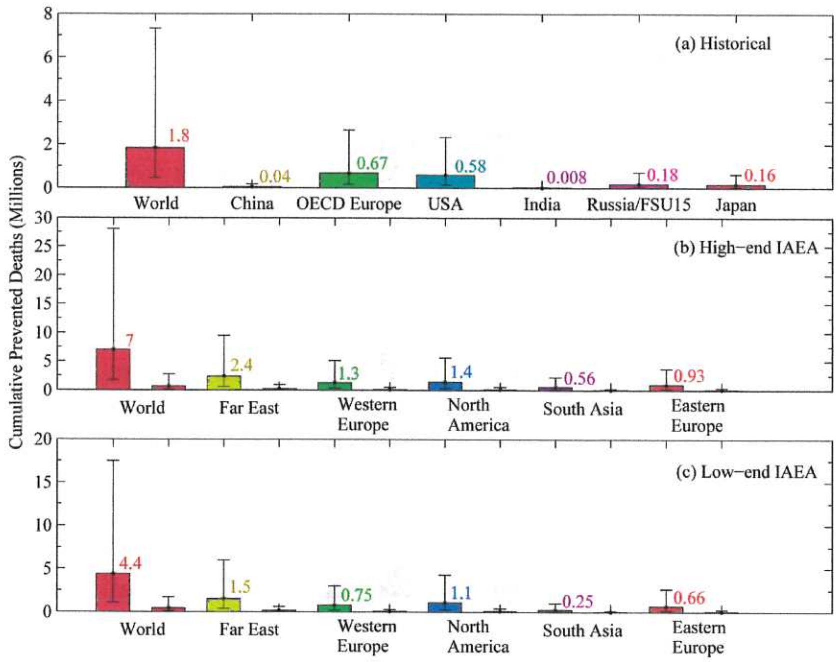

Figure 2. Cumulative net deaths prevented assuming nuclear power replaces fossil fuels. (a) Results for the historical period in this study (1971–2009), showing mean values (labeled) and ranges for the baseline historical scenario. Results for (b) the high-end and (c) low-end projections of nuclear power production by the UN IAEA[6] for the period 2010–2050. Error bars reflect the ranges for the fossil fuel mortality factors listed in Table 1. The larger columns in panels b and c reflect the all coal case and are labeled with their mean values, while the smaller columns reflect the all gas case; values for the latter are not shown because they are all simply a factor of ~10 lower (reflecting the order-of-magnitude difference between the mortality factors for coal and gas shown in Table 1). Countries/regions are arranged in descending order of CO_2 emissions in recent years. FSU15 = 15 countries of the former Soviet Union, and OECD = Organization for Economic Cooperation and Development.

Russia have affirmed plans to increase their current nuclear capacity by greater than 3-fold, greater than 12-fold, and 2-fold, respectively (see Table 12.2 of ref 2). In Japan, the future of nuclear power now seems unclear; in the fiscal year following the Fukushima accident, nuclear power generation in Japan decreased by 63%, while fossil fuel power generation increased by 26% (ref 15), thereby almost certainly increasing Japan's CO_2 emissions.

Although our analysis reflects mortality from all stages of the fuel cycle for each energy source, it excludes serious illnesses, including respiratory and cerebrovascular hospitalizations, chronic bronchitis, congestive heart failure, nonfatal cancers, and hereditary effects. For fossil fuels, such illnesses are estimated to be approximately 10 times higher than the mortality factors in Table 1, while for nuclear power, they are ~3 times higher.[16] Another important limitation is that the mortality factors exclude the impacts of anthropogenic climate change and development-related differences, as explained in the Results and Discussion section. Aspects of nuclear power that cannot meaningfully be quantified due to very large uncertainties (e.g., potential mortality from proliferation of weapons-grade material) are also not included in our analysis.

Proportions of fossil fuels in our projection cases are assumed to be fixed (for the purpose of determining upper and lower bounds) but will almost certainly vary across years and decades, as in the historical period (Figure 1). The dominance of coal in the global average electricity mix seems likely for the near future though (e.g., Figure 5.2 of ref 2). However, even if there is large-scale worldwide electric fuel switching from coal to gas, our assessment is that the ultimate GHG savings from such a transition are unlikely to be sufficient to minimize the risk of dangerous anthropogenic climate change (unless the resulting emissions are captured and stored), as discussed in the next section.

RESULTS AND DISCUSSION

Mortality. We calculate a mean value of 1.84 million human deaths prevented by world nuclear power production from 1971 to 2009 (see Figure 2a for full range), with an average of 76 000 prevented deaths/year from 2000 to 2009 (range 19 000–300 000). Estimates for the top five CO_2 emitters, along with full estimate ranges for all regions in our baseline historical scenario, are also shown in Figure 2a. For perspective, results for upper and lower bound scenarios are shown in Figure S1 (Supporting Information). In Germany, which has announced plans to shut down all reactors by 2022 (ref 2), we calculate that nuclear power has prevented an average of over 117 000 deaths from 1971 to 2009 (range 29 000–470 000). The large ranges stem directly from the ranges given in Table 1 for the mortality factors.

Our estimated human deaths *caused* by nuclear power from 1971 to 2009 are far lower than the avoided deaths. Globally, we calculate 4900 such deaths, or about 370 times lower than our result for avoided deaths. Regionally, we calculate approximately 1800 deaths in OECD Europe, 1500 in the United States, 540 in Japan, 460 in Russia (includes all 15 former Soviet Union countries), 40 in China, and 20 in India. About 25% of these deaths are due to occupational accidents, and about 70% are due to air pollution-related effects

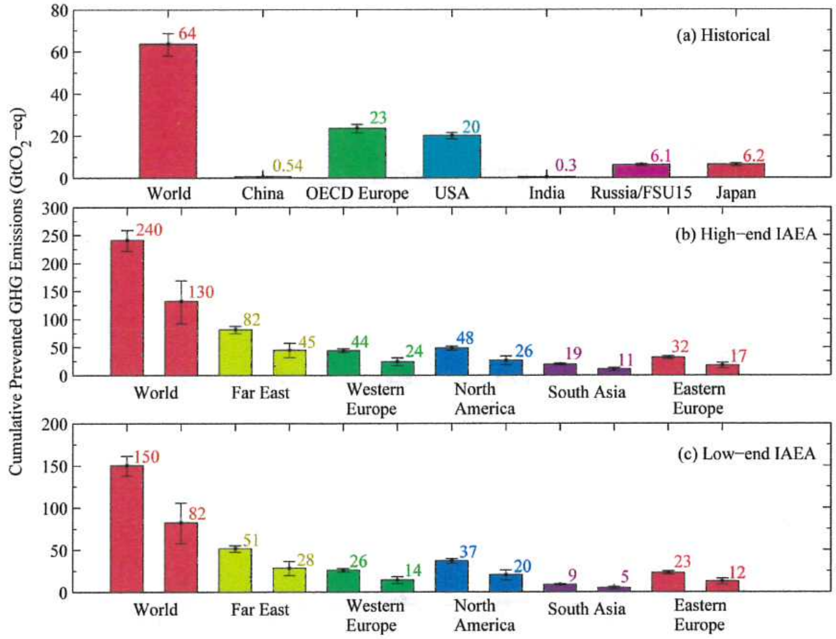

Figure 3. Cumulative net GHG emissions prevented assuming nuclear power replaces fossil fuels. Same panel arrangement as Figure 2, except mean values for all cases are labeled. Error bars reflect the ranges for the fossil fuel emission factors listed in Table 1.

(presumably fatal cancers from radiation fallout; see Table 2 of ref 16).

However, empirical evidence indicates that the April 1986 Chernobyl accident was the world's only source of fatalities from nuclear power plant radiation fallout. According to the latest assessment by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR),[17] 43 deaths are conclusively attributable to radiation from Chernobyl as of 2006 (28 were plant staff/first responders and 15 were from the 6000 diagnosed cases of thyroid cancer). UNSCEAR[17] also states that reports of an increase in leukemia among recovery workers who received higher doses are inconclusive, although cataract development was clinically significant in that group; otherwise, for these workers as well as the general population, "there has been no persuasive evidence of any other health effect" attributable to radiation exposure.[17]

Furthermore, no deaths have been conclusively attributed (in a scientifically valid manner) to radiation from the other two major accidents, namely, Three Mile Island in March 1979, for which a 20 year comprehensive scientific health assessment was done,[18] and the March 2011 Fukushima Daiichi accident. While it is too soon to meaningfully assess the health impacts of the latter accident, one early analysis[19] indicates that annual radiation doses in nearby areas were much lower than the generally accepted 100 mSv threshold[17] for fatal disease development. In any case, our calculated value for global deaths caused by historical nuclear power (4900) could be a major overestimate relative to the empirical value (by 2 orders of magnitude). The absence of evidence of large mortality from past nuclear accidents is consistent with recent findings[20,21] that the "linear no-threshold" model used to derive the nuclear mortality factor in Table 1 (see ref 22) might not be valid for the relatively low radiation doses that the public was exposed to from nuclear power plant accidents.

For the projection period 2010−2050, we find that, in the all coal case (see the Methods section), an average of 4.39 million and 7.04 million deaths are prevented globally by nuclear power production for the low-end and high-end projections of IAEA,[6] respectively. In the all gas case, an average of 420 000 and 680 000 deaths are prevented globally (see Figure 2b,c for full ranges). Regional results are also shown in Figure 2b,c. The Far East and North America have particularly high values, given that they are projected to be the biggest nuclear power producers (Figure S2, Supporting Information). As in the historical period, calculated deaths caused by nuclear power in our projection cases are far lower (2 orders of magnitude) than the avoided deaths, even taking the nuclear mortality factor in Table 1 at face value (despite the discrepancy with empirical data discussed above for the historical period).

The substantially lower deaths in the projected all gas case follow simply from the fact that gas is estimated to have a mortality factor an order of magnitude lower than coal (Table 1). However, this does not necessarily provide a valid argument for such large-scale "fuel switching" for mitigation of either climate change or air pollution, for several reasons. First, it is important to bear in mind that our results for prevented mortality are likely conservative, because the mortality factors in Table 1 do not incorporate impacts of ongoing or future anthropogenic climate change.[16] These impacts are likely to become devastating for both human health and ecosystems if recent global GHG emission trends continue.[1,3] Also, potential global natural gas resources are enormous; published estimates for technically recoverable unconventional gas resources suggest a carbon content ranging from greater than 700 $GtCO_2$ (based on refs 23 and 24) to greater than 17 000 $GtCO_2$ (based on refs 24 and 25). While we acknowledge that natural gas might play an important role as a "transition" fuel to a clean-energy era due to its lower mortality (and emission) factor relative to coal, we stress that long-term, widespread use

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of natural gas (without accompanying carbon capture and storage) could lead to unabated GHG emissions for many decades, given the typically multidecadal lifetime of energy infrastructure, thereby greatly complicating climate change mitigation efforts.

GHG Emissions. We calculate that world nuclear power generation prevented an average of 64 gigatonnes of CO_2-equivalent ($GtCO_2$-eq), or 17 GtC-eq, cumulative emissions from 1971 to 2009 (Figure 3a; see full range therein), with an average of 2.6 $GtCO_2$-eq/year prevented annual emissions from 2000 to 2009 (range 2.4−2.8 $GtCO_2$/year). Regional results are also shown in Figure 3a. Our global results are 7−14% lower than previous estimates[8,9] that, among other differences, assumed all historical nuclear power would have been replaced only by coal, and 34% higher than in another study[10] in which the methodology is not explained clearly enough to infer the basis for the differences. Given that cumulative and annual global fossil fuel CO_2 emissions during the above periods were 840 $GtCO_2$ and 27 $GtCO_2$/year, respectively,[11] our mean estimate for cumulative prevented emissions may not appear substantial; however, it is instructive to look at other quantitative comparisons.

For instance, 64 $GtCO_2$-eq amounts to the cumulative CO_2 emissions from coal burning over approximately the past 35 years in the United States, 17 years in China, or 7 years in the top five CO_2 emitters.[11] Also, since a 500 MW coal-fired power plant typically emits 3 $MtCO_2$/year,[26] 64 $GtCO_2$-eq is equivalent to the cumulative lifetime emissions from almost 430 such plants, assuming an average plant lifetime of 50 years. It is therefore evident that, without global nuclear power generation in recent decades, near-term mitigation of anthropogenic climate change would pose a much greater challenge.

For the projection period 2010−2050, in the all coal case, an average of 150 and 240 $GtCO_2$-eq cumulative global emissions are prevented by nuclear power for the low-end and high-end projections of IAEA,[6] respectively. In the all gas case, an average of 80 and 130 $GtCO_2$-eq emissions are prevented (see Figure 3b,c for full ranges). Regional results are also shown in Figure 3b,c. These results also differ substantially from previous studies,[9,10] largely due to differences in nuclear power projections (see the Supporting Information).

To put our calculated overall mean estimate (80−240 $GtCO_2$-eq) of potentially prevented future emissions in perspective, note that, to achieve a 350 ppm CO_2 target near the end of this century, cumulative "allowable" fossil CO_2 emissions from 2012 to 2050 are at most ~500 $GtCO_2$ (ref 3). Thus, projected nuclear power could reduce the climate-change mitigation burden by 16−48% over the next few decades (derived by dividing 80 and 240 by 500).

Uncertainties. Our results contain various uncertainties, primarily stemming from our impact factors (Table 1) and our assumed replacement scenarios for nuclear power. In reality, the impact factors are not likely to remain static, as we (implicitly) assumed; for instance, emission factors depend heavily on the particular mix of energy sources. Because our impact factors neglect ongoing or projected climate impacts as well as the significant disparity in pollution between developed and developing countries,[16] our results for both avoided GHG emissions and avoided mortality could be substantial underestimates. For example, in China, where coal burning accounts for over 75% of electricity generation in recent decades (ref 14; Figure S3, Supporting Information), some coal-fired power plants that meet domestic environmental standards have a mortality factor almost 3 times higher than the mean global value (Table 1). These differences related to development status will become increasingly important as fossil fuel use and GHG emissions of developing countries continue to outpace those of developed countries.[11]

On the other hand, if coal would not have been as dominant a replacement for nuclear as assumed in our baseline historical scenario, then our avoided historical impacts could be overestimates, since coal causes much larger impacts than gas (Table 1). However, there are several reasons this is unlikely. Key characteristics of coal plants (e.g., plant capacity, capacity factor, and total production costs) are historically much more similar to nuclear plants than are those of natural gas plants.[13] Also, the vast majority of existing nuclear plants were built before 1990, but advanced gas plants that would be suitable replacements for base-load nuclear plants (i.e., combined-cycle gas turbines) have only become available since the early 1990s.[13] Furthermore, coal resources are highly abundant and widespread,[24,25] and coal fuel and total production costs have long been relatively low, unlike historically available gas resources and production costs.[13] Thus, it is not surprising that coal has been by far the dominant source of global electricity thus far (Figure 1). We therefore assess that our baseline historical replacement scenario is plausible and that it is not as significant an uncertainty source as the impact factors; that is, our avoided historical impacts are more likely underestimates, as discussed in the above paragraph.

Implications. More broadly, our results underscore the importance of avoiding a false and counterproductive dichotomy between reducing air pollution and stabilizing the climate, as elaborated by others.[27−29] If near-term air pollution abatement trumps the goal of long-term climate protection, governments might decide to carry out future electric fuel switching in even more climate-impacting ways than we have examined here. For instance, they might start large-scale production and use of gas derived from coal ("syngas"), as coal is by far the most abundant of the three conventional fossil fuels.[24,25] While this could reduce the very high pollution-related deaths from coal power (Figure 2), the GHG emissions factor for syngas is substantially higher (between ~5% and 90%) than for coal,[30] thereby entailing even higher electricity sector GHG emissions in the long term.

In conclusion, it is clear that nuclear power has provided a large contribution to the reduction of global mortality and GHG emissions due to fossil fuel use. If the role of nuclear power significantly declines in the next few decades, the International Energy Agency asserts that achieving a target atmospheric GHG level of 450 ppm CO_2-eq would require "heroic achievements in the deployment of emerging low-carbon technologies, which have yet to be proven. Countries that rely heavily on nuclear power would find it particularly challenging and significantly more costly to meet their targeted levels of emissions."[2] Our analysis herein and a prior one[7] strongly support this conclusion. Indeed, on the basis of combined evidence from paleoclimate data, observed ongoing climate impacts, and the measured planetary energy imbalance, it appears increasingly clear that the commonly discussed targets of 450 ppm and 2 °C global temperature rise (above preindustrial levels) are insufficient to avoid devastating climate impacts; we have suggested elsewhere that more appropriate targets are less than 350 ppm and 1 °C (refs 3 and 31−33). Aiming for these targets emphasizes the importance of retaining and expanding the role of nuclear power, as well as energy efficiency improvements and renewables, in the near-term global energy supply.

■ ASSOCIATED CONTENT

Supporting Information

Comparison with avoided GHG emissions in projection periods of prior studies; figures showing upper and lower bounds for prevented deaths and GHG emissions assuming nuclear power replaces fossil fuels from 1971–2009, projections of nuclear power production by region, and total electricity production from 1971–2009 by fuel source for the top five CO_2-emitting countries and OECD Europe. This material is available free of charge via the Internet at http://pubs.acs.org.

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Author Contributions

P.K. designed the study with input from J.H.; P.K. performed the calculations and analysis and wrote the paper with feedback from J.H.

Notes

The authors declare no competing financial interest.

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<u>Testimony before the Assembly Committee on Energy and Utilities</u>
<u>November 18, 2015 (AJ Gross)</u>

Hi, my name is AJ Gross, and I am a senior studying nuclear engineering at the University of Wisconsin-Madison, and I am also licensed by the Nuclear Regulatory Commission to operate the University of Wisconsin's Research Nuclear Reactor. As a reactor operator, part of my job is to do radiation surveys every month, as well as before anyone outside of our staff enters the lab. We also measure any radiation levels in the air, the water in our reactor systems, and of any surrounding labs that utilize radioactive sources. We do this because the safety of the general public, as well as that of our staff, is our number one priority. Our reactor is not unique in this respect. The nuclear industry has a safety culture around it unlike any other industry. Thanks to the standards set by the Nuclear Regulatory Commission, every reactor in the country has to consider any scenario that could result in a safety risk to the public, and have several systems in place to prevent them. Even if the proposed legislature is passed, all reactor designs will still need to be determined to be safe by the nuclear regulatory commission. This only happens after the Nuclear Regulatory Commission spends years looking at every single aspect of the reactor and making sure that every single piece of the reactor can operate safely for many years to come. This regulatory process combines to make nuclear power one of the safest sources of energy available in the United States.

If any members of the Wisconsin Legislature would like to learn more about nuclear power, I would be more than happy to arrange a tour of the University's Research Reactor.

Testimony before the Assembly Committee on Energy and Utilities
November 18, 2015 (Richard Rolland)

Hello, I'm Richard Rolland. I grew up in Waukesha County and I am now a student at the University of Wisconsin-Madison finishing my Master's and Bachelor's dual degree program in nuclear engineering this December. Additionally, I will have a double major in economics and a certificate in physics for my undergraduate studies.

I came here today to discuss a major reason why this legislation should pass and why nuclear power in Wisconsin should be promoted. This reason is that nuclear power is a reliable source of energy. An example of this occurred during the 2014 polar vortex, which I'm sure we all remember. According to Forbes contributor James Conca, nuclear and wind helped prevent major blackouts throughout the nation. In fact, he stated "without nuclear, we would have had blackouts, and real public danger at these temperatures" [1]. This was due to nuclear power plants having 95% of their total capacity operational during the polar vortex compared to fossil fuels which had a significant amount of shutdowns due to the temperature experienced and the shortage of natural gas during the polar vortex [1] [2]. With wind producing minimal amounts of the necessary power required for the electric grid [3]; having a supply of nuclear energy in cases of low temperatures and other abnormal environmental events will keep the state's power on.

Additionally, nuclear energy has the benefit of operating reliably throughout the year. Nuclear reactors in the nation spend, on average, approximately 90% of their time producing electricity, with the rest of the time mostly consisting of scheduled outages [3] [4]. In comparison, wind and solar power spent approximately 30% of their time in 2014 producing electricity sporadically [3]. Therefore, nuclear power provides a major benefit to our electrical grid by allowing for a reliable power source throughout the year.

Before I end, I want to mention another reason to allow the option for nuclear power plants to once again be built in Wisconsin. This is due to the Nuclear Engineering Department at the University of Wisconsin-Madison. According to U.S. News' rankings in 2015, University of Wisconsin is tied for 3rd place for the best graduate nuclear engineering school in the country [5]. Sadly, extraordinary talent from the state is being lost as many nuclear engineering graduates are leaving the state due to minimal career opportunities in Wisconsin. To not even allow for potential construction of a nuclear power plant in Wisconsin due to the moratorium is unwise based on the vast educational knowledge of nuclear engineering present in the state.

The Wisconsin legislature should vote to pass this piece of legislation to allow nuclear power the opportunity to make the Wisconsin energy grid more reliable and to allow Wisconsin nuclear engineering graduates to be a part of Wisconsin's energy industry. Thank you.

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Wisconsin Utility Investors, Inc.

10 East Doty Street, Suite 500, Madison, WI 53703-3397 – (608) 663-5813 – Fax (608) 283-2589 – wui@wuiinc.org

TO: Assembly Committee on Energy and Utilities

FROM: James A. Buchen
Executive Director, Wisconsin Utility Investors Association

DATE: November, 18, 2015

RE: Assembly Bill 384

The Wisconsin Utility Investors association (WUI) supports Assembly Bill 384 that removes various unique restrictions that currently serve as a virtual moratorium on the construction of new nuclear power plants in Wisconsin.

While there are currently no plans to build any new nuclear facilities in Wisconsin, as we consider our future energy needs all reasonable options should be on the table.

Nuclear energy has proven to be a safe and reliable source of power in Wisconsin. The Point Beach facility and, prior to closure, the Kewaunee plant have been a significant part of the base load generating capacity in this state for decades. They have demonstrated that nuclear power plants can operate safely and be good neighbors while having minimal impact on the environment.

Energy policy is increasingly driven by environmental considerations. As the US Environmental Protection Agency seeks to limit carbon dioxide emissions from fossil fuel combustion in power plants, consideration of nuclear power becomes more significant. Among the options for low or no carbon emission sources of electricity, the potential for wind and solar power in Wisconsin is limited by our geography and climate. Hours of sunlight grow short in the winter and the wind does not blow reliably during periods of peak demand for electricity. As a result, the potential for nuclear power to provide a reliable and virtually carbon free source of base load electricity becomes an increasingly attractive option.

Assembly Bill 384 would eliminate the specific requirements in the statute that prohibit construction of new nuclear facilities unless there is an operational nuclear waste disposal facility. This serves as a virtual moratorium on new nuclear power in Wisconsin because the Federal Government has been unwilling to establish such a facility, despite having identified an appropriate site and effective technology. With passage of the bill nuclear power could be considered as a viable option in Wisconsin.

WUI is a statewide association of individual investors in Wisconsin public utilities. The majority of our members are retired individuals with modest portfolios that provide retirement income. The mission of the organization is to educate members on utility issues, operations and finances as well as protect shareholder interest in the public policy arena by ensuring that utilities can operate in a fair regulatory environment and provide a fair rate of return to shareholders.

WUI respectfully requests your support of Assembly Bill 384.

clean wisconsin
your environmental voice since 1970

11/18/15

To: Members, Assembly Committee on Energy and Utilities

From: Amber Meyer Smith, Clean Wisconsin

SUBJECT: Opposition to AB 384/SB 288

Clean Wisconsin is committed to clean, safe, cost-effective electricity to meet our energy needs, and to thoroughly review all solutions to our global warming crisis. We recognize that climate change threatens environmental damage of unprecedented magnitude, and that reducing atmospheric carbon concentrations has taken on new urgency in the last decade.

In order for Wisconsin to take a lead in addressing the climate crisis, and to most cost effectively meet the carbon reductions spelled out in the Clean Power Plan, Clean Wisconsin continues to prioritize:

1) Controlling demand and use of electricity by promoting energy conservation and efficiency. Conservation and efficiency are the cheapest and cleanest electricity resources, and will relieve the pressure for any new generation.
2) Supporting the decommissioning of dirty, costly coal facilities.
3) Advocating that our energy needs be met with cleaner, safer, and homegrown renewable energy sources like wind, solar and bioenergy.

Because of this overarching goal for clean, safe, homegrown and cost effective electric generation, nuclear power remains an undesirable and impractical alternative for the following reasons:

It is the most capital-intensive and costly way to generate electricity. The estimated cost for building just one new nuclear reactor is more than \$10 billion. In fact, the two most recent nuclear reactors being built in the United States – in Georgia and South Carolina – are years behind schedule and billions of dollars over budget. Both projects are using the modular design AP1000 reactor, which is the "advanced nuclear energy" called out in AB 384/SB 288, which are the latest in nuclear technology and were expected to streamline construction time and costs. Four similar projects using the AP 1000 reactors in China are also experiencing cost overruns and construction delays.

The costs for waste disposal continue for decades after decommissioning. In Wisconsin, municipal governments currently bear the costs for the stockpiles of nuclear waste in their community. By comparison, wind energy combined with storage technology is already cheaper than building a nuclear reactor; and the price of solar has decreased drastically in recent years. Clean energy can deliver 5 times more pollution-cutting progress per dollar. New nuclear power costs between 9-13.4¢ per KWh while wind is around 2.3¢ per KWh.

Nuclear plants are not a silver bullet for addressing climate change. They cannot be built fast enough to have a significant impact on global warming for many decades. New plants take at least 10 years for construction and licensing, and even adding another 50 nuclear reactors nationwide (they are currently about 100) would only reduce emissions by 10%. In contrast, energy efficiency and renewable energy investments can have immediate and significant impacts. In addition, uranium mining, milling, leeching,

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Action Network

plant construction and decommissioning all produce greenhouse gases, so it is not an energy source devoid of emissions.

Unlike renewables, the fuel is not homegrown. Wisconsin pays for mining and creating fuel in other states and countries rather than taking advantage of the solutions we have in our manufacturing, forestry, and agricultural sectors to produce renewable energy that keeps money in our own economy.

The technology has not advanced to the point that there is a safe way to manage the dangerous, high-level radioactive wastes that are the necessary by-product. Dry-cask storage is only a temporary fix to the problem of growing stockpiles of spent fuel rods that will take tens of thousands of years to be rendered safe. There is still no permanent repository or safe way to transport spent fuel to such a location.

Nuclear reactors present a significant safety risk from weather, security, and even simple human error. The consequences of radiation exposure can be catastrophic for generations to come, and the impact to the environment is devastating. Fukushima is the most recent example, but Chernobyl and Three-Mile Island remain as part of the nuclear legacy. The federal government estimates that a major accident at just one of Wisconsin's reactors could cost over $40 billion in property damage alone.

We are also concerned about the part of the bill that adds nuclear energy to the energy priorities law. In particular, we question prioritizing it over gas generation, which could be a large part of Wisconsin's immediate efforts to reduce carbon emissions through the Clean Power Plan. That re-prioritization just doesn't make sense.

Over 30 years ago, after the meltdown at Three Mile Island, Wisconsin put into place common sense safeguards around new nuclear power development until there is a safe repository for spent fuel, and the technology becomes safe and cost-effective. Clean Wisconsin has supported efforts to change that law when they were considered as part of a larger effort to advance all forms of clean energy, and we will continue to support our current nuclear laws until there is a broader discussion about Wisconsin's energy future.

Instead of focusing on technologies that are extremely expensive, risky and will take decades to build, we ask that the Legislature focus on real, immediate and cost-effective solutions to reduce carbon emissions through increases to our energy efficiency and renewable energy systems.

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Frank Lasee

WISCONSIN STATE SENATOR

FIRST SENATE DISTRICT

Senator Lasee's Testimony

Assembly Bill 384/Senate Bill 288

Ending Wisconsin's Nuclear Power Moratorium

Wisconsin is in constant competition with other states for jobs. Overbearing regulations place Wisconsin at a disadvantage compared to other states that have fewer regulatory hurdles.

One example of unnecessary regulatory hurdles is Wisconsin's moratorium on building new nuclear power plants in our state.

While Wisconsin currently has an excess generating capacity, and the economics of constructing new nuclear power plants aren't favorable right now, it's important for us to remove the regulatory hurdle now so that Wisconsin might be more attractive to nuclear power plant development in the future.

Nuclear power makes no emissions to the air. With ever increasing federal regulations against conventional means of power generation, new nuclear power plants may become economically viable in the near future. We need to eliminate the regulations now so that Wisconsin is not excluded from competing for future nuclear power plants and the hundreds of great paying jobs that come with them.

Each nuclear power plant that could be built in the future creates hundreds of jobs both for construction and for staffing each new plant. Over 500 employees are needed to staff each operating nuclear power plant. It makes good sense to eliminate the nuclear power moratorium in Wisconsin.

Chair: Committee on Insurance, Housing and Trade

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