The Future of Nuclear Energy in Wisconsin

Reenergizing the Debate
Madison, WI
October 22-23, 2003

Nuclear Energy: A Future Energy Source for Wisconsin

John D. Wiley, Chancellor
October 22, 2003

I would like to begin by thanking the Department of Engineering Physics for organizing this conference, and thanking all of you for attending and participating. Earlier this week, we hosted a workshop on campus, entitled "The Chancellor's Energy Policy Forum," although I have to tell you the Chancellor had nothing to do with organizing or naming it. At that Forum, numerous speakers mentioned the role nuclear energy currently plays in Wisconsin, and speculated about future energy options and choices. So it is very timely to have today's Conference on one of those options, and I was asked to provide some remarks to open the conference.

Now, I'm asked to open lots of conferences around here, most of which are on topics I am not expected to know much, if anything, about. In this case, however, I suspect I was asked at least partly because the organizers know I have been a long-time, outspoken proponent of nuclear power as the safest, cleanest, most cost-effective alternative we have for producing electricity. I have also been a proponent of electricity, itself, as the safest, cleanest, most versatile, and most cost-effective alternative we have for transporting energy from source to customer. So the two really go hand-in-hand. Nevertheless, I'm probably going to surprise almost everyone by saying relatively little about nuclear power *per se*.

We have lots of experts here who can speak about all aspects of nuclear power much more knowledgeably and authoritatively than I can. I was trained as a physicist, and I did take courses in nuclear physics, but that doesn't make me an expert on nuclear power. I didn't even like the courses that much. And, although I ended up teaching in an Electrical Engineering department, I'm not an expert on electricity generation and distribution, either. My area of technical expertise involves semiconductors, microelectronics, and materials science – solid state physics.

On the other hand, like all of you, I'm a citizen, and I have an inherent interest in things that affect me, my family, and society at large. I try to use whatever tools I have to inform myself about those things and then act and advocate according to the best information I can gather.

I'm going to begin by doing something to you that I always hated to have done to me when I was younger. I'm going to tell you what it was like in "the old days." I'm going to provide a context for the evolution of my views, and some of the reasons why I have concluded that Wisconsin, the US, and the world should have and will have nuclear power in its future. I'm going to tell you why I have concluded that those who dispute that assertion most strenuously are not simply wrong, but are being misled into taking positions that are contrary to their own most passionately held values and convictions. Bear with me for a few minutes and I'll eventually make the "old days" relevant to this Conference.

I grew up in Southern Indiana (Evansville, IN – about the size of Madison) in the 1940s and 50s. The house I grew up in was heated by a coal-fired furnace. Every month or so, a truck showed up in our driveway and delivered several tons of coal through a chute into our basement. One of my jobs from about age 10 was to shovel coal into the stoker and clean out the furnace firebox by removing the so-called "clinkers."

Shoveling the coal was bad enough. People who haven't had to be around it probably don't realize how nasty and dirty raw coal is. But the worst part was removing the clinkers. As soon as the furnace door was opened, the basement filled with dense clouds of yellowish-brown smoke. You couldn't see even a few feet through it. Your eyes burned, and it was impossible to breathe. I had to learn to hold my breath while I used six-foot tongs to pull out glowing, smoking chunks of clinker, drop them in metal buckets, and run upstairs to take them outside and dump them in the alley behind our house.

A couple of times a week, the city collected all the cold clinkers. They returned later as crushed slag (cinders) and were spread on the alley surface as loose "pavement." That was recycling in the 1950s: The slag from coal combustion, containing every toxic heavy metal in the periodic table, was redistributed as a loose pavement for kids to play on. I probably still have pieces of cinder embedded in my knees and elbows.

Every house in my neighborhood – every house in the city – had a coal furnace. Winter in Evansville was one permanent gray/yellow/brown haze. Clothes hung out to dry turned gray before they were dry. Freshly washed cars developed an ash film coating by the end of the day. I don't recall ever seeing a star in the winter.

What I do recall very clearly is the day that furnace was removed. A few workmen came in and removed that huge octopus from our basement. I say "octopus" because that's what it looked like. The furnace, itself occupied about a third of the basement, and it had round pipes – ducts – going off in all directions, carrying hot air to the rooms upstairs. The furnace and all the hot-air ducts were wrapped in asbestos paper tape. All that was ripped out in a few hours and taken away. I have no idea where they took it, but I imagine it was all thrown into a surface landfill.

When I got home from school that day, the first thing I did was run to the basement to see the new gas-fired octopus. I was astounded. The coal was gone, and there was a whole empty basement. Tucked in a corner was a small, quite, maintenance-free gas furnace with a few flat ducts hugging the ceiling. Within a few months, my asthma disappeared forever, and the old coal bin had become a workshop. I've often thought that was probably the single greatest quality-of-life change I've ever experienced. Over the next few years, more and more people converted to gas, until the Southern Indiana Gas and Electric Company's power plant was about the only remaining source of coal smoke.

We live in the present, and for most of us the relevant present only goes backward and forward a few years at most. What I mean by that is we tend to identify past trends and make plans and projections of the future for only a few years. We forget or ignore too much of the past and fail to imagine far enough into the future. The problem with that is that many of the most important and informative trends are only apparent over decades or centuries, and some of the things we do or don't do or don't anticipate today can have huge consequences (one way or the other) decades or centuries in the future.

Our students, today, are almost universally aware of and concerned about air and water pollution, about hazardous materials and recycling, about land use and habitat protection. And that's great. But air pollution today is measured with sensitive instruments. Fifty years ago, when I was shoveling coal, no instruments were needed: Air pollution could be seen, tasted, and felt by wiping your hand over any exposed surface. Lead bricks and cyanide and all manner of other useful but dangerous substances could be purchased at the hardware store. Elemental Mercury was easily purchased at the pharmacy. Virtually any chemical was available by mail order from the companies that made and sold chemistry sets. Waste of all sorts went down the drain into a lake or river, or into the garbage can, and from there to a landfill, and as far as I know, no one though any more about it. I was able to purchase (by mail order!) a vial of radioactive Iodine 131 for a high school science experiment after the AEC did a brief inspection of the lead safe I had built, tested my Geiger counter, asked me a few questions, and gave me a simple letter of permission.

Scientific evidence and environmental awareness have changed all this and more. We've made enormous progress. The impact of all environmental regulation and remediation to date has been a huge net positive contribution, not only to the air, water, and land, but to human health, quality of life, human life expectancy, and the economy. But, in acknowledging this, an environmental status report in 2003 should not be overly focused on near-term incremental goals. Rather, it should look far enough into the future to anticipate and plan for the inevitable. In particular, it should anticipate the day when we have no further economically viable fossil fuels.

Although comprehensive records of pollution were not kept before the early 1970s, and only poorly before about 1980, it is possible to document dramatic improvements, but it is also easy to see just how far we have yet to go. Just a few examples from the most recent Statistical Abstract of the United States will serve to illustrate (and I'm going to restrict this to air pollution): From 1970 to 2000 the amount of PM10 (explain) particulates injected into the atmosphere annually has dropped from 13 million tons to 5.5 million tons. About 4% of what remains is due to electric utilities, and much of the reduction is due to pollution controls on coal plants and increased reliance on natural gas. Over that same period, Sulfur Dioxide emissions have gone from 31 million tons to 18 million tons. In this case, about 62% of what remains is due to coal-burning utilities. Most other pollutants have also gone down, some to near insignificance. One major counter-trend is Carbon Dioxide. From 1970 to 2000, CO2 emissions have gone from 1355 million metric tons/year to 1583 million metric tons/year, and virtually all of this (99%) is due to so-called energy sources. That means things that burn some carbon-containing substance: gasoline, diesel fuel, fuel oil, natural gas, and coal being the major sources. I don't have a breakdown for the fraction attributable to utilities, but I'm sure that is calculable. Given that about 20% of our electricity is currently produced by nuclear plants, and that nuclear plants require very little pollution for their construction or decommissioning, and emit nothing at all during operation, these numbers would be vastly worse if we did not now have about 104 nuclear plants in operation. Nuclear power has already saved lots of lives and slowed global warming considerably. Why do I say that?

The overwhelming scientific consensus is now that global warming is a real phenomenon, and that man-made sources of so-called greenhouse gases, including principally the massive injections of CO2, are the cause. Some people dispute that, but I don't think they have much credibility any longer – too much hard evidence just keeps accumulating in confirmation of both the phenomenon, itself, and its primary cause. And, while some few individuals still dispute the reality of global warming as a long-term trend, I haven't heard of anyone who argues that intentional, anthropogenic global warming and global climate change would be a good strategy for our species to undertake. On the contrary: I think even the remaining skeptics would agree that if it's a real phenomenon, then we need to do whatever is necessary to stop it, because even the mildest predictable consequences are extremely expensive and disruptive, and the endpoint consequences are utterly unpredictable but not likely to be good. If we spent the twentieth century creating this problem out of ignorance, we certainly can no longer claim ignorance and fail to spend the twenty-first century fixing it.

What that means to me is that we have to find as many ways as we can to stop burning things. A very significant part of the problem is CO2, and essentially all of that comes from combustion. The combustion also produces other nasty byproducts, so it's not just CO2 reduction we're after, but let's focus on that.

The two biggest contributors are motorized vehicles and electric utilities. Let's take those one at a time.

Going from gasoline to Compressed Natural Gas (CNG) would help. CNG produces less CO and CO2 than gasoline, and fewer particulates and other pollutants (except for NOx, which is about the same for both). But the reductions are very modest. After even small increases in population (more drivers), we'll be back where we started. Plus, we will eventually run out of natural gas. It doesn't matter how large you think the reserves are, or what you assume about undiscovered reserves. Pick a number and a rate of usage and you can estimate when it will all be gone. The same is true of gasoline, for that matter, and for all fossil fuels. We will eventually run out. That means to me that the long-term goal needs to be vehicles powered in some way other than by burning anything that contains Carbon. Burning pure Hydrogen would work, but we can only get sufficient quantities of Hydrogen by hydrolyzing water, and that takes energy, too. At best, it takes exactly as much energy as we get back when we burn it, and that energy would have to be electric energy produced somehow. The bottom line is that we have no alternative but to transition to electrically powered vehicles.

Well, let's be honest, here: that would eliminate emissions from the *vehicles*. But whether the vehicles are powered by batteries, or by hydrogen in fuel cells, or by any other viable technology, the "juice" for recharging batteries, or for hydrolyzing water to free the hydrogen, would need to come from a generator somewhere. If that generator is burning something and emitting pollution, then (after taking efficiencies into account) we will have made the global problem worse.

Which brings us to the generator. Here is the only picture I'm going to show you.

[Show diagram of CO2 vs life cycle return and explain/discuss]

Wind generation and nuclear fission are essentially equivalent in terms of environmental impact, and so much better than anything else that there is really no contest. Note that both these technologies are about 100 times better than coal and natural gas in BOTH dimensions, and very significantly better than all other options, including photovoltaics, by extremely large margins.

When quantitative differences become large enough, they become qualitative differences. If your salary goes from $20,000/year to $25,000/year, that's wonderful: It means your standard of living goes up by enough to notice. But your life is otherwise not much changed. You're simply a little better off in essentially the same circumstances. If it goes from $20,000 to $60,000, that's enough to make a really big difference: You may be able to move from an apartment to a house, for example, and still afford to dress and eat better, and to drive a better car. A factor of three is a big and possibly even a qualitative difference. But if your salary increased by a factor of ten, it would go to $200,000/year, and if it increased by a factor of 100, you would be making

$2million/year. The difference between $20,000/year and $2 million/year is emphatically not just a quantitative difference: It is a qualitative difference. It puts you in a whole different world of existence. That's the nature of the difference between conventional coal and gas technology on the one hand and nuclear or wind technology on the other hand. The latter are not just quantitatively better, they are SO MUCH better that they are qualitatively in a different world.

Before going on, let me point out that wind generation would not be capable of providing 100% of the baseload power of any national or even regional system because the wind isn't blowing continuously, and may be lowest exactly when you need the most generation. It is the nature of electrical supply and demand that, without some kind of large-scale energy storage mechanism, the generation must always match the demand almost perfectly, so that match must be re-evaluated and adjusted continuously. Nevertheless, in a sufficiently large, interconnected system, and with wind sources sufficiently distributed geographically, there will always be a market somewhere for wind generation as long as the wind contribution is not too large a
fraction of the total generation. Therefore, it is not necessary to insist on burdening wind power with a costly and polluting (over the life cycle) storage system.

With this insight {credit Fernando for convincing me} it is clear that wind power and nuclear fission are "slam-dunk" winners for the clean and sustainable generation of electricity. To switch from a basketball to a baseball metaphor: **They simply knock everything else out of the park**. For long-term sustainability and absolute minimization of greenhouse gas emissions, there are no current practical alternatives to some appropriate combination of wind and nuclear generation.

What about conservation? Conservation is a vitally important part of the mix. In a world of finite resources, it is irresponsible to be wasting anything, because waste contributes to the problem we are trying to eliminate. Every unit of conservation delays several units of capital investment in additional generation. But after all opportunities for conservation have been exhausted, the fundamental problem will remain and, unless we change our energy economy, that problem will eventually grow back to current levels. We will end up right back where we are today. So conservation can delay the day of reckoning, but it cannot stave it off indefinitely by itself.

I am left with the conclusion that the only feasible, sustainable options we have are wind and nuclear, and that both of them must be included in the mix, eventually phasing out everything else. I can't see any rational arguments that conclude otherwise. So why all the opposition to nuclear? Essentially all the opposition is based on assertions that nuclear power reactors and the nuclear waste associated with them present frightening and unacceptable risks to the public.

Risk assessment is an interesting mix of quantifiable probabilities and unquantifiable psychology. People make wildly inaccurate judgments about relative risks depending on their level of familiarity with the sources of those risks. We are much less concerned about common, everyday activities that can and do kill us quickly and in great numbers than we are about rare, exotic things that have the potential to kill us slowly, or painfully, or after a long delay, but that actually seldom ever happen. We are also loath to admit that it is moral or even possible to attach a quantitative value to human life, or to compromise safety for practical reasons. But all of that is nonsense. We can and do make such compromises daily.

We may not like it, but we accept an annual highway death toll of more than 40,000/year. We fuss and fret over the scandal of automakers who balk at modifications that have the potential to save a few lives. But the fact is we have the technology to build cars that could reduce the death toll to near zero. There are cars today that can crash into each other or into stationary barriers at more than 100 miles per hour, flip in the air, tumble end-over-end for hundreds of feet while throwing off tires and body panels, crash into yet another barrier, and then burst into flames as the driver gets out and walks away, uninjured. You can see them almost any day on ESPN. The problem is, that level of safety costs more than $1million per vehicle.

We have decided – society has decided, without ever explicitly thinking of it in these terms – that we are willing to accept some small risk of death to have cars that cost less than $1million, because the alternative of insisting on near absolute safety is that most of us will have no cars at all.

Properly designed and operated, nuclear power plants are exceedingly simple and exceedingly safe. Most people don't realize that all the "nuclear" part of a nuclear power plant does is generate heat without burning anything. It is the very essence of a simple, elegant heat source that, during operation, produces no pollution of any sort that can affect anyone.

Nuclear reactors are so simple that they sometimes occur naturally without any human intervention of any sort. There are places where the concentration of naturally occurring Uranium in the ground is high enough that, when water saturates it and provides the right moderation for the neutrons, the region "turns on" as a nuclear reactor and generates considerable heat. When the water boils off and the area dries out, the reactor turns off automatically and stays off until the next rainfall or other saturation, at which time the cycle repeats, and this continues quietly, and unremarkably for hundreds of thousands of years.

Nuclear reactors are so safe that in nearly 50 years of operation at more than 100 different US sites, not one person has ever died as a result of any routine radiation-related event. I can't think of any industry that has a better safety record. And keep in mind that this essentially perfect record has been achieved with an installed base of different, unique, one-of-a-kind reactors, most of which

were designed 40-50 years ago. They are like Model-T Fords compared to the modern Mercedes we could mass produce and install today.

Arguing against nuclear power on the basis of some hypothetical and wildly improbable future event is far worse, from an objective point of view, than arguing against the construction of golf courses on the grounds that some future golfer may be killed by lightning. (And, by the way, about 50 people are killed by lightning annually – maybe 2500 deaths over the fifty-year fatality-free history of nuclear power.) If the same safety standards being insisted upon by nuclear power opponents were applied elsewhere in the economy, no modern manufactured product or process would be allowed, and we would all be living in cold, dark caves, with life expectancies of some 25 years.

Let me conclude by saying that for the last 40 years or so, I have thought nuclear was the most logical and sensible way to generate electricity primarily because it is such an elegant, efficient, safe, and sustainable way to do it. Given that option, I thought it was foolish to waste valuable carbon-containing coal, oil, and gas for something as mundane as generating heat by burning them. I was also offended by the inefficiency of taking all that carbon that nature had spent billions of years sequestering and concentrating for us, and then turning it into a gas and blowing it back into the air where it will be hard to recover. As a materials scientist, I would much rather use fossil hydrocarbons to make polymeric building and fabrication materials to replace wood and metal, for example. I still feel that way, and that, alone is sufficient reason to support nuclear generation. But I am now also convinced that the environmental arguments are so compelling that we have no other choice.

I'm now looking forward to sitting back and hearing the real experts confirm what I've just asserted. At least I hope that's what I'll hear. Thank you, and I hope you have an informative and productive conference.