

Remembering How to Make Cheap Nuclear Electricity
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by

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Mr Chairman, Senator Reid, ladies and gentlemen. It is an honor to be invited to talk to you today.

In the USA we now emit 11% more CO₂ than in 1990; and at Kyoto we promised to reduce CO₂ emissions to 8% below 1990 levels in 10 years for a decrease of 19% below today's levels. If all the electricity now generated by nuclear power were to be generated by coal that would increase CO₂ another 8% making it more difficult to meet our commitment if we abandon nuclear power. As we ponder whether the US will meet this commitment made at Kyoto, one fact stands out. That of all the alternate fuels nuclear power is alone in producing no appreciable particulate air pollution, not contributing to global warming and, if we develop a breeder reactor being able to produce power for 100,000 years at modest cost. The present problem is that the both the construction cost and the operating cost has risen between two and threefold in the last considerably in the last 25 years. It is more expensive than fossil fuels and begins to approach the costs of some of the solar energy alternatives.

25 years ago, Maine Yankee nuclear power plant had just been completed for \$180 million, or \$200 per cwt installed capacity. Connecticut Yankee nuclear power plant was producing electricity at 0.55 cents per kwh busbar cost, some part of which was paying off the mortgage. The operating cost was perhaps only 0.4 cents per kWh. Now, 25 years later, the most recently completed nuclear power plants cost at least \$2000 per installed kW of capacity, 10 times the 1972 cost, and Connecticut Yankee is being permanently shut down because it costs 3.7 c/kwh, 9 times the 1972 cost even though the mortgage is fully paid. Yet inflation can only account for a part - perhaps a factor of 2.5 to 3 - of this.

In most technologies there is a learning curve and are cheaper as time goes on. In this technology we have an unlearning or forgetting curve. Numbers that I have seen from France give an average cost of nuclear electricity including all costs, of 2.9 cents/kwh, whereas a similar number in the US averaged over all plants operating in 1995 was 5 cents/kwh (this ignores costs of plants, like Shoreham, which were abandoned for political or other reasons). More generally, the *operating* costs of the best operated nuclear power plants in the USA are now about 1.8 cents per kwh compared to a coal cost of about 1.6 cents a kwh. Construction costs are much more. In 1980 the question was "Why should any utility company go nuclear"? In 1998 the question is "why should any utility company stay nuclear?"

Not one unless the costs can come down or unless the environmental costs of coal burning can be internalized to increase the coal price. I have pointed out this problem before (Wilson 1994, 1996) and note that if the present trend continues half our nuclear power plants will be gone in 10 years and we will have no nuclear power plants at all in the USA by 2017. Yet if Parkinson (1957) is right the regulatory authority will still be expanding many years later!

Why has the cost gone up? What must we do to bring it down again? Various ideas include the following:

- in 1970 manufacturers built turnkey plants or otherwise sold cheap reactors as loss leaders. But this can only account for a small proportion of the capital cost.
- Construction costs generally have risen in this time.
- it may be that in 1972 we had good management and good technical people. But why has management got worse when that has not been true for other technologies?
- it is probable that nuclear power plants are safer today than they were in 1972. But it would be hard to argue that the actual safety improvements have cost that much money. Most are a result of more careful thought using such approaches as event tree analysis, but without excessive hardware expense.
- many people have suggested that the problem is that the regulation is more than needed for adequate safety and this increases the cost (Towers-Perrin 1995). In particular that regulation is too prescriptive and not based upon performance.
- The response to many regulations is to increase staff. The staff numbers at the Dresden power plant went from 250 in 1975 to over 1,300 today (Benhke 1997). This costs money and it is far from clear that it improves safety.
- The problem is not unique to the USA. In the UK the Atomic Energy Authority had to spend a lot of money making the plant as earthquake proof as an operating reactor - yet the inventory of dangerous material is far less and the danger of recriticality remote (Hill 1997).

I want to address here the problem of regulation and the intricate and complex relationship between regulator and licensee. Although not an expert, I claim one advantage: I look on the problem from outside and I keep the three fundamental societal aims in mind.

The US NRC was separated in 1974-5 from the old Atomic Energy Commission to separate the promotional role of nuclear energy from the regulatory role. It was already geographically separated by putting the promotional arm in Germantown and the regulatory arm of AEC in Bethesda. But unlike the mandate given to the AEC by the Atomic Energy Act of 1945, the NRC has no mandate to keep power plants in operation - only to ensure that the power plants operate without undue risk to the public. It was left to ERDA and now the Department of Energy to promote nuclear energy and to provide the balance. It is important to realize that the utility companies cannot

and will not by themselves perform this function of balance. The utility companies are under close local or regional control, and historically have shown extreme reluctance to challenge any regulatory body. There is a great unbalance in power. A regulator often has the ability to keep a power plant shut down for an extra day - an action which costs the utility company \$1,000,000 per day. There is no counterbalance to ensure that this power is used wisely and well. The Nuclear Regulatory Commission has been sued in the courts, (in what seems to be the preferred procedure in the USA for obtaining balance) by one or another group opposed to nuclear power, but to the best of my knowledge has not been sued by utility companies. Any regulator will automatically adjust his strategy to minimize lawsuits - and probably that is easiest done by ensuring that the number of lawsuits from each side is equal. If there is no one actively promoting nuclear energy, therefore, the regulation will inevitably become more strict and will force unnecessary price rises until price competition destroys the industry.

How can we regain the balance in regulation? I submit that two steps are necessary. The first is a procedure to decide to regulate nuclear power in a more efficient way (including deciding upon how much regulation is necessary) and the second to find a group which will play the active promotional role that is so necessary in the US system and those patterned after it.

The first step was already begun by the first Commission to take office some 14 years ago when astronaut Bill Anders was chairman. After 2 years of public hearings started by the AEC the NRC set some radiation and safety guidelines. (NRC 1975). The Commission proposed that expenditure on radiation exposure reduction should be made if it costs less than \$1,000 per ManRem, now doubled to \$2,000 (Kress 1994) - a number higher than anyone in the hearing had proposed. A corollary was implied but not explicitly stated. If a proposed dose-reducing action would cost more than this, it should NOT be done.

In the 1980s the Advisory Committee on Reactor Safeguards (ACRS) made a study that led to the promulgation by the Commission of a set of SAFETY GOALS. These were appropriately related to the safety of individuals living near a power plant. The risk must be appreciably less (10% or so) of that of another electricity generating facility. But it was recognized that such safety goals were difficult to implement and a subsidiary safety goal was promulgated that the frequency of core melt must be kept to less than 1 in 10,000 per reactor-year. Safety improvements must be made to keep the core melt frequency below that amount. Although not stated, it was implied that steps to decrease core melt frequency still further were unwarranted and it was not worth the expense to undertake them. For simplicity I will address this "intermediate" safety goal here but the same argument can be applied to the more fundamental safety goal.

There is a fundamental problem in implementing GOALS as opposed to issuing or following regulations. There is no definitive way of proceeding. But studies can be made retrospectively to see whether they are met. Clearly the \$2,000 per Man Rem is a safety goal. An independent study (Tengs et al. 1995) suggests expenditures in the nuclear industry for RADWASTE have been 1000 times this amount. It seems that either the regulations (in this case probably the Technical specifications) are stricter than needed, that the industry is spending more than the regulations call for, or the total amount of money is so small it is not worth worrying about. The procedure does not, however suggest how they be relaxed or whether the cost decrease is large enough to be worth

the bother. I suggest that the nuclear plant operators and the NRC, perhaps aided by IAEA since it is an international problem, should study the matter with some urgency.

Similarly the ACRS has repeatedly stated that it is not sensible to regulate on the basis of a Probabilistic Risk Assessment (PRA). But a PRA CAN be used to discuss retrospectively whether reactors that were designed and operate under existing regulations meet the goals. If they meet the goals, fine. If they do not regulations must be tightened. On the other hand if the safety goals are met with a large margin maybe the regulations can be relaxed. Indeed the important parts of a PRA can now be put on a small PC or laptop so that the effect of any small change in procedures can be quickly calculated.

An example of how use of this concept can prevent unnecessary regulation occurred some 8 years ago. A very careful PRA was done by the Nuclear Regulatory Commission (NRC 1987) for a number of "typical" nuclear power plants including an early Boiling Water Reactor (BWR). In all cases it was found that the core melt probability was LESS than one in ten thousand per year. There are uncertainties about this calculation, and there has been some discussion about whether one should take the median, the mean or the mode of the probability distribution. I have argued elsewhere that one should take the mean, and do so in what follows. An immediate use of this argument was discussed at an NRC research advisory group meeting. The NRC staff was suggesting addition of safety devices to BWR Mark I reactors to improve safety. I, as a member of that advisory committee, pointed out that these reactors met the safety goal with flying colors. Either the safety goals were wrong, or the NRC's research program that produced NRC 1150 was useless, or the staff suggestion was excessive. The committee agreed with me and so did the director of regulation. In this case the staff suggestion was dropped. Unfortunately this was an isolated instance. It was also an instance in which regulation was not increased rather than an instance in which regulation was actually decreased. Reducing regulatory requirements is FAR more difficult. However, I urge that NRC have a formal and MUCH more rapid procedure for examining regulations.

Shortly thereafter I was asked to be Chairman of a task force reviewing the safety of the nuclear power plants in Taiwan on behalf of the Minister of Foreign Affairs. The director of regulation in Taiwan told us that he accepted the idea of guidelines but wanted to have the core melt frequency to be less than 1 in 100,000. I asked why he wanted it to be so low when the careful studies by NRC thought that 1 in 10,000 was low enough. The reply was that "industry can meet it". Maybe so. In the event, I believe that Taiwan did NOT change the safety goal. Since the power plants, which were US designed and very well run meet the 1 in 10,000 goal easily that leaves wiggle room for the utility company (TAIPOWER) to cope with occasional lapses of their staff and an occasional overzealous regulator. The ROC AEC can, by using PRA can easily justify their goal to the public and TAIPOWER can proudly tell the public that they are doing even better.

Hard though it is to reduce the severity of a regulation, it is harder to forgive a deliberate violation of regulations even when that violation does not result in any safety goal being exceeded. But again I urge immediate and rapid effort in this direction. If there has been a procedural violation the NRC must of course act in some way because such violations can escalate. But I suggest a graded response. The power plant might be shut down, as were the four power plants at Millstone and Connecticut 2 years ago, but only until NRC can determine whether or not the

violation led to exceeding the safety goals. With fast computers a PRA can be set up to do such an analysis within a week or two at most. If a safety goal was NOT violated, it seems a clear indication that the regulation or technical specification was too strict and it could be modified and the reactor allowed to restart with no further "punishment".

Of course utility company staffs and in particular utility company managements are often the most to blame. We have seen in the late 1970s how TVA went in a few years from one of the best utility companies to one of the worst. In the early 1990s Ontario Hydro went from having the highest plant availability of any reactors in the world to being among the lowest. Many observers attribute each of these to a change in top management. There is less agreement on whether the management was malevolent (antinuclear) or merely incompetent. The Ontario hydro board used to have one person who understood nuclear technology - now it has none. (But the management incorrectly in my view insist that the only problem is on the shop floor) But the regulatory structure should be able to cope with this. If it is necessary (and I do not believe it is) to always have perfect regulators and perfect management to run nuclear power, there is no hope that costs can be reduced. Fortunately the PRA confirms for us that light water reactors are a forgiving technology. Northeast Utilities had clear management problems. The costs were one of the highest and in an effort to reduce costs there was, and is a temptation to cut corners. In addition there are cases of inadequate regulation. That usually comes from inadequate alertness. There are also occasional "whistle blowers" who for whatever reason raise issues that they feel have been neglected. In such situations there is a temptation for a regulatory authority to tighten up all round in the hope of reassuring the public. Indeed several successive Chairmen of NRC recently seem to have felt it politically desirable to do something dramatic to tighten up regulations in an attempt to convince the public that they are no pushover for industry. I do not believe that it does reassure the public. I believe it makes matters worse, by implying that the regulatory action had been too lax. Far better would be to study, know, understand and explain to the public the effect that such problems have on safety. As noted above, we now have the techniques of PRA available to ensure the completeness which is otherwise so difficult. I suggest a joint approach by utility companies - perhaps through the Institute of Nuclear Power Operations (INPO) - the NRC and academia (hopefully with funding from DOE) to study the critical interaction between regulator and licensee - always with a background of the risks of other energy technologies as discussed in Comparative Risk Assessment (CRA). Even though regulatory procedures vary between countries IAEA could also play an important role.

The above would NOT be promotion of nuclear power. It is less clear to me how to achieve my second step and who should play the active role of promoter of nuclear power. Who should constantly call the regulator to task when he takes actions that exceed his own goals. In the USA that would have to involve lawsuits because that is where the action finally occurs in any subject. I suspect that is not politically possible for the Department of Energy (DOE) and to that extent the political concept of 1973 when the AEC was broken up was fatally flawed. Other mechanisms must be found.

In 1987 six Long Island residents started a lawsuit nominally against Long Island Lighting Company but really against New York State, (with a supporting brief by a Department of Energy more friendly to nuclear power than the present department) in an effort to prevent them dismantling the Shoreham nuclear power plant without filing an environmental impact statement - and in that

statement would have inevitably had to contradict the comments of Governor Cuomo's staff in the previous EIS that nuclear power is environmentally advantageous. This suggests to me that a publicly minded group of scientists, who are concerned about the three environmental issues with which I began this paper should form a group to be watchdogs and file suit to enforce fair regulation when appropriate. Unless something is done, I do not think that nuclear power in the short term will survive.

The NRC's recent record in the above respects is abominable. I mentioned above that the radwaste regulations cost 1000 times too much. The actions at Millstone point were vastly exaggerated also. Over 2 years ago I asked the Chairman of the Commission by FAX what the technical problems were and what effect they had on safety. I have had no reply but after 2 months I did get a reply from the Director of Regulation, since resigned, who gave me a 2 page comment on procedural violations. NO ONE within or without the commission has challenged my contention, repeated many times since then that the effect of the procedural violation that caused the shut down was a change of perhaps 1 in 100,000 per year in core melt probability. The NRC should have been able to realize within 2 weeks that this is one tenth of their safety goal and that the draconian action was unnecessary.

Although many people, in Congress and in the press talk about the evils of the old AEC it is noteworthy that in those "bad old days" response to criticism was much faster and more substantive. 25 years ago when I started my interest in energy and environmental matters I wrote to the Chairman of the AEC a 2 page letter with a dozen or more criticisms. 3 days later Dr Glenn Seaborg, not a secretary, telephoned me and invited me to spend 3 days with him and his staff going over detailed responses. During the first 3 hours in Dr Seaborg's office I was introduced to each of the appropriate Assistant Secretaries who answered my queries to the best of my ability and directed me to further sources. That was the secrecy and cover up about which we repeatedly hear complaints.

The cost of the over regulation at Millstone is huge and seems to have been deliberately understated in many reports so far. I take it here to be the busbar cost of replacement electricity of about \$3,000,000 a day or 2 billion dollars so far. The effect on public health is also huge. Supposing the replacement electricity to come from a mixture of fossil fuels and hydro power in the average proportions, each power plant replacement costs over 50 premature deaths a year from air pollution, (Wilson and Spengler 1996) or over 400 deaths so far. Other utility companies have got the message: "Get out of nuclear power as fast as you can".

Indeed it is calculations such as this that led former Senator Tsongas to declare "I do not see how anyone who prefers burning coal to nuclear power can call himself an environmentalist".

I urge NRC to begin once again to act in the public interest and according to their own safety goals. To change regulations to in either direction to match these goals. When there is a procedural violation that has safety consequences that are within these goals to give a slap on the wrist rather than an execution. I urge each commissioner to take the approach of W.S Gilbert's Mikado who made it "an object all sublime.... to make the punishment fit the crime". Let us hope that it will be achieved in time - before the nuclear industry is destroyed.

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