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The Role of Nuclear Energy to Address Global Climate Change Issues

An AIChE Nuclear Engineering Division White Paper

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AIChE Government Relations Committee

October 2000

The Role of Nuclear Energy to Address Global Climate Change Issues

In most scenarios envisioned for global warming, the predicted environmental consequences resulting from carbon dioxide emissions are a major concern to the principal world powers. While debates continue, many world scientific leaders recognize that curtailment of carbon dioxide emissions is a reasonable insurance policy. The Kyoto conference on global warming was an initial attempt to draw the major world powers together to address the issue, and ambitious goals were laid out for each nation to follow in order to slow down the accumulation of carbon dioxide in the atmosphere. However, many world leaders doubt if the goals can be met, given expected increases in world energy demand. Large increases in third world populations are predicted, as well as increasing demands in third world countries to improve the standard of living with corresponding competition for scarce energy resources. Given this predictable increase in world demand for energy and the corresponding greenhouse effects, industry should prepare for this paradigm shift to reduce greenhouse gas emissions. The AIChE believes that chemical engineers can play a major role in achieving significant reductions in carbon dioxide emissions by identifying and developing technologies to reduce greenhouse gas emissions and employing energy conservation and efficiency measures.

One major contributor to carbon dioxide emissions is found in the generation of electricity. Large electrical power plants seem to be capable to meet those new demands of the developing nations given the trend for third world populations to migrate from a rural setting to an urban setting. There are three related factors that will have a tremendous bearing on electrical generation throughout the World and may change the prospects for nuclear power: 1.) the increasing strain on the world's energy resources and the food base needs driven by population growth; 2.) the desire by the developing world to increase its standard of living significantly above present conditions, and 3.) deteriorating environmental conditions resulting from global warming, deforestation, pollution and other factors. It is clear that any even-partial solution to this "trilemma" must be large and far-reaching in magnitude. Hence, there is strong evidence for a continuing need for large central power plants that can tap into existing grids in the US, as well as other countries. Renewable and dispersed electricity sources should and certainly will play a role; however, their overall contribution to worldwide electricity production is likely to remain small, at least in the short run.

The AIChE Nuclear Division believes that a key element of this strategy is the use of nuclear power to eliminate or displace some of the carbon dioxide emissions resulting from fossil fuel generation of electricity. Furthermore, AIChE recognizes nuclear power is one possible solution that should be considered providing

remaining political and technical issues are resolved. Thus, nuclear power should be poised to make a significant contribution to both national and worldwide energy/environment problems.

It was earlier in this century that scientists discovered a natural force within the atom capable of energy releases nearly a million times larger than electronic (chemical) forces. Such "nuclear" forces were responsible for the genesis and sustenance of stars, including the sun, and the synthesis of the chemical elements. It is essentially the ability to extract huge amounts of energy from relatively small volumes (or masses)) that gives nuclear energy environmental and economic advantages. To illustrate this, Table 1 shows the energy equivalents of 1 kg (2.205 lb) of carbon-based chemical versus two types of nuclear fuels:

Table 1. Energy Equivalent of 1 kg of Fuel Material in Kilowatt-hours

Fuel Material and type	Kilowatt-hrs of Electricity
Firewood (carbon based renewable)	1
Coal (carbon-based fossil fuel)	3
Oil (carbon-based fossil fuel)	4
Natural uranium (nuclear fuel)	50,000
Plutonium (nuclear fuel generated by nuclear process and recycled)	6,000,000

("Nuclear Energy in the 21st Century." International Atomic Energy Agency, Director General Hans Blix, Beijing, China , 1997.)

The high energy density of nuclear fuels has offered economy and convenience with minimal undesirable effluents produced during power plant operation. The major waste produced, spent nuclear fuel, is minuscule in volume when compared to the prodigious amounts of gas emitted into the earth's atmosphere and in some cases fly ash produced from the burning of fossil fuels. Most power plants use natural gas, coal, oil, nuclear, or hydropower as an energy supply to generate electricity. As can be seen in Table 2 below, only nuclear power and hydropower are capable of generating large quantities of electricity with virtually no emission of carbon dioxide.

Table 2. Carbon Dioxide produced per 1,000,000 Kilowatt-hours of Electricity produced

Power source	Metric tons
Natural Gas	150
Coal	265
Oil	220
Nuclear power plant	0
Hydropower	0

Nuclear power generation does, of course, also produce wastes. Management of waste from nuclear power generation is a controversial subject due to the high radio toxicity of the waste and the lack of clear direction of national waste management policies. Nuclear power generates a small amount of waste, but that waste contains highly radioactive substances that must be effectively sequestered from human intrusion or biosphere dispersion for time periods several times that of written human history. Currently, most of the nuclear waste is stored on the reactor site awaiting the availability of either interim or long term geologic storage/disposal facilities. The Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) are evaluating and proposing regulatory scenarios for the long term geologic repository which conflict in the approach to risk management. The Department of Energy is also developing long term storage capabilities for nuclear waste generated by nuclear power plants. However, there are geological concerns, such as at Yucca Mountain, which must be addressed, particularly in light of local residents' concerns regarding nuclear waste disposal in their communities.

Most technical problems regarding safe transportation to the storage site and long term storage have been addressed. Spent nuclear fuel (SNF) is currently transported by rail, road, and ship in Europe and elsewhere. Transportation casks for SNF shipped in the US are subject to NRC and Department Of Transportation (DOT) regulations, and require a robust design capable of withstanding extreme fires, water immersion, drops, and crashes. Long term disposal requirements depend on the type of waste. Storage of spent nuclear fuel and high level wastes requires a deep underground site, which, in turn, requires attention to geologic stability, integrity and the ability of the site to withstand the decay heat load over a 50 year time frame. In New Mexico, the recently opened Waste Isolation Pilot Plant site in a deep salt formation presently provides for the disposal of intermediate materials from the cold-war era. Research at Yucca Mountain in Nevada has shown no insurmountable technical difficulties to using that site for the disposal of spent fuel. However, the problems regarding approach to risk management remain and should be addressed to the appropriate regulatory body for resolution. The public should be informed of both the benefits of nuclear power generation, as well as risks associated with long term management of nuclear waste.

Nuclear energy options offer several potential low cost solutions to reduce greenhouse gases. Specific examples are life extension for current plants, increasing the availability of current installations, developing more efficient plants, simplified regulations for nuclear plants, new generation of nuclear reactors, and assigning carbon dioxide abatement credits to utilities with nuclear plants. However, a lifecycle study should be undertaken to better understand opportunities for cost savings as well as areas of greatest cost uncertainty (e.g., the cost of waste disposal represents a large uncertainty).

Keeping currently operating plants in the US on stream is an inexpensive way to maintain base capacity as opposed to replacing the nuclear plant with a new gas fired power plant. Over the next 5-10 years many of the nuclear plants will reach the end of current operating licenses. The American Nuclear Society has stated that these plants can be safe to operate for 70-80 years. Yet many of these plants will be in a position where the plant

owners will be faced with spending several millions of dollars to extend the life of the plant or spending hundreds of millions to build new plants. Without these measures, nuclear plants reaching end-of-life are likely to be replaced by generating capacity that use carbon based fuels and thus contribute to the global carbon dioxide emissions problems.

Clearly the regulatory environment must be set up so that it is cost effective for both the utilities and the consumer for the safe extension of the life of the plant; such licensing efforts are currently underway for several nuclear plants. The United States must make it economical to extend the life of current nuclear plants since these plants can present 30-40 years of operational data to validate the life extension decision. Research programs are needed to examine the effects of aging on performance of reactor systems and, in particular, safety systems.

As a start in this direction, Congress has appropriated funds to begin work on power plant life extension programs in conjunction with industry. This program has potential for widespread application throughout the utility industry. Principal areas that are likely to be among the first areas studied are making current plants more efficient. By reducing the "house load,' or the plant's internal electricity needs, by incorporating modern technology, and by increasing the availability of current plants, this efficiency may be achieved. If the efficiency improvements continue, the utilities can get more out of their current investments and reduce the overall costs of generating electricity. The government could also seek long range solutions that will encourage a new generation of reactors to provide more acceptable solutions to issues currently encountered in nuclear plants: e.g. safety, proliferation, waste disposal. These new reactors would likely be good candidates for US firms to market to other developing countries, thus re-establishing the US market position and providing a positive action to reduce the trade deficit. US dominance in the new reactor market would also maintain the US influence on the non-proliferation of nuclear weapons related technology.

A change in the regulatory environment is necessary. A new paradigm is needed to establish cooperation between the regulators and the regulatees in a manner where nuclear plants can be operated in a safe and cost effective manner. The relationship between the NRC and the utilities tends to be adversarial - the licensee is often unnecessarily restricted and excessive cost expenditures are imposed. The utility is forced to go beyond the boundary where a reasonable safety analysis would take them and establish extraneous requirements that tend to exceed sound engineering practices. Analyzing a coal-fired plant in a similar manner would point out areas of excess conservatism. A transition to a risk-informed regulatory system, wherein risks are analyzed and a cost/benefit study can be used to reach decisions has been advocated by the industry. This approach would encourage cost-efficient risk-based decisions and regulations. Acceptance of this approach should be embraced by the regulatory agencies and use of this approach should be accelerated. The standardization of regulations would speed along the approval process and, subsequently, will help to protect the safety of the public.

Finally, there are areas in which the United States can benefit by encouraging nuclear power aside from its being a reasonable insurance policy as protection against global warming. Strategic goals such as controlling weapons proliferation and ensuring safe operation of nuclear facilities around the world may be realized by maintaining a leadership position in nuclear power. US manufacturers will reap economic benefits, thus diminishing the trade deficit.

AIChE Nuclear Engineering Division

The American Institute of Chemical Engineers Nuclear Engineering Division was founded in 1954. It provides a forum for the members of the AIChE who are active in industrial, research, educational, or government organizations involved with the nuclear fuel cycle, and it disseminated factual information on nuclear energy to members as well as the general public, and acquaints other members of the Institute with the achievements and problems of the nuclear energy industry. The Division also facilitates the application in the chemical industry of new technologies developed I the nuclear industry and initiates and coordinates actions by the AIChE in the field of nuclear energy.

AIChE
Making a World of Difference

The American Institute of Chemical Engineers (AIChE), founded in 1908, is a non-profit, professional association that provides leadership in advancing the chemical engineering profession. Our membership of more than 57,000 is made up of individuals who work in industry, government, academia, and consulting, and includes students and retirees.

Our members are creative problem solvers who apply scientific knowledge and technical expertise to integrate product design and manufacturing technology to make useful materials at a reasonable cost and in the safest manner possible. They play a key role in critical industries such as petrochemicals, petroleum, biotechnology, ceramics, electronics, fibers, food, glass, paper, plastics, primary metals, and specialty chemicals. Chemical engineering is at the forefront of research on environmental protection, process safety, and hazardous waste management to assure the safe and environmentally sound manufacture, use, and disposal of chemical products.

AIChE sponsors pioneering research through the Center for Waste Reduction Technology, the Center for Chemical Process Safety, and other technology partnerships. These research efforts are geared toward examining new technologies that can solve the problems of today and tomorrow.

To further our goal of promoting excellence in the development and practice of chemical engineering, we promote public understanding of the profession and its roles in resolving societal issues, provide forums to advance chemical engineering in theory and practice, create opportunities for individual chemical engineers to enhance their professional skills and capabilities, uphold and advance high professional standards and ethics, and support excellence in education.

AIChE disseminates information about the latest innovations in chemical engineering through its publications such as *AIChE Journal*, *Chemical Engineering Progress*, and *Environmental Progress*.

The Institute's government relations activities are informational and educational. They are geared towards using the expertise of our members to provide sound technical information to government officials and others involved in public policy issues that impact the practice of chemical engineering and the industries and organizations where chemical engineering is utilized.

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