Pergamon

Progress in Nuclear Energy, Vol. 29 (Supplement), pp. 19-22, 1995
1995 Elsevier Science Ltd
Printed in Great Britain
0149-1970/95 $29.00

0149-1970(95)00022-4

BARRIERS TO USING NUCLEAR POWER FOR MITIGATION OF GLOBAL WARMING

M. W. Golay

Department of Nuclear Engineering, Massachusetts Institute of Technology,
Cambridge, MA 02139-4307, U.S.A.

ABSTRACT

It has lately been suggested that nuclear power technologies could be used to mitigate potential global warming. Doing this would give nuclear power technology a new role, and would lead to its widespread deployment worldwide. When examined carefully several barriers to accomplishing this goal are evident, even should the uncertainties of global warming become reduced enough that it could be treated as an established fact. These barriers involve the need for alternative forms of nuclear energy, uranium resource limitations, technology development requirements and difficulties in widespread deployment of nuclear power plants. Overcoming the barriers may prove to be much more difficult than has been appreciated to-date, and could strongly influence the future research and development agenda for nuclear and associated technologies.

KEYWORDS

Global warming; nuclear power; hydrogen economy; developing countries; breeder reactors.

THE NEED FOR ALTERNATIVE FORMS OF NUCLEAR ENERGY

Nuclear energy is capable currently of producing only electricity. Most industrialized countries are becoming increasingly electrically-dependent, and current nuclear technologies can serve them well. It is also capable of producing high temperature heat, and of desalinating large amounts of water. However, in order to have an important role in mitigating global warming it is important for nuclear power to also provide direct substitutes for fossil fuels. This is especially crucial for meeting the energy needs of developing countries, where the greatest growth of greenhouse gas emissions can be expected in the future and where the electrical infrastructure is weak.

The most attractive way of doing this using current technologies is via production of hydrogen, electrolytically. Thermally- and chemically-based methods of hydrogen production might also be employed, but none has yet been developed to the stage of industrial application. It is usually a mistake to anticipate the future in much detail. Perhaps much better nuclear-based fossil fuel substitutes can ultimately be developed. However, today hydrogen production is feasible, either in the developing or developed countries. However, problems of safety in hydrogen transport, storage and consumption would still require development of new technologies. Ways to do this have been identified, but not greatly exploited.

Potential hydrogen transport and storage methods include use of metal hydrides (which can obtain hydrogen densities greater than that of liquid hydrogen), pressurized glass-lined storage vessel (the glass is needed to prevent embrittlement of the metal vessel via formation of metallic hydrides), and adding hydrogen atoms to a hydrocarbon carrier compound, which is then de-hydrogenated at the time of use (for example, the reaction $2CH_4 \leftrightarrow C_2H_6 + H_2$ would serve this purpose).

URANIUM RESOURCES AND TECHNOLOGY DEVELOPMENT REQUIREMENTS

The only certainty about the future is that our expectations will be wrong. However, an example analysis illustrates the typical rate at which uranium resource reduction might be expected should nuclear power be used in a serious attempt to mitigate global warming. The model used for the world energy economy is that of Edmonds and Reilly (1986). The assumptions used are summarized in Table 1. These assumptions correspond to current rates of world population growth for the coming several decades, some success in improving energy end-use efficiencies, increasing electrification of world energy economy, increasing use of nuclear power to provide electricity, an increase in worldwide electricity, an increase in worldwide levels of per-capita energy use to a level typical of the industrialized countries, but no use of nuclear power to produce any energy product except electricity. The results indicate that expensive ($\leq$ \$130/kg), identified and speculative uranium resources would be depleted within about 20 years of using light water reactors (LWRs) to mitigate global warming (Schenler and Golay, 1992). These resources would be produced at costs roughly six times as high as current prices for uranium.

It is well-known that resource depletion dynamics are much more complicated than is stated here. Typically, mineral consumption leads to increasing prices which stimulate greater exploratory activity to identify additional resources. It also stimulates improvements in technologies for mineral discovery and extraction. Conceivably, substantially more uranium could be produced than are indicated by current IAEA estimates (OECD, 1992). For example, should the ultimately produced Uranium resource prove to be ten times greater depletion using LWRs would not occur until after 2100. Regardless of the actual ultimate production of Uranium, these time scales are important for they indicate that large-capacity breeder reactor technologies would be required soon in a serious nuclear power response to global warming.

During recent years high costs and concerns about the dangers of a global plutonium economy have greatly decelerated development of such reactors. Effectively, the reactors receiving greatest developmental emphasis currently—passively safe and advanced evolutionary LWR concepts—are both ill-suited for a serious global warming response. Such a response would demand that worldwide plutonium security be much greater than it is currently. One means of improving the weapons proliferation resistance of plutonium economy would be to require that any recycled plutonium always be accompanied by strong γ-emitting

Table 1. World nuclear trajectory assumptions

1. World Population is Projected to Level Off at 11 Billion by 2040.
2. World Electricity Consumption per Capita is Projected to Rise from 17% to 60% of U.S. per Capita Consumption by 2020, and to Remain Constant Thereafter.
3. The fraction of All Energy Provided by Electricity is Projected to Rise from 25% to 40% by 2040.
4. Electrical Energy Efficiency Savings Grow from 0% in 1990 to 40% in 2010.
5. The Electricity Demand Curve Flattens, With Base Load Rising from 60% to 80% of Peak Load.
6. The Fraction of Electricity Supplied by Nuclear Power Rises from 25% in 1990 to 50% by 2010.

materials, such that illicit diversion would be costly, cumbersome and easily detected. The pyroprocess of spent fuel being developed for the Integral Fast Reactor (IFR) provides an example of such a process. Notably, the needed technologies still await development, particularly those for detecting the transport of illicit nuclear materials.

DIFFICULTIES IN WIDESPREAD DEPLOYMENT OF NUCLEAR POWER PLANTS

Since inception of efforts to develop simplified, passively safe reactors it has often been asserted that it would be feasible to deploy such reactors in technologically primitive countries. It is interesting that most of the evidence available to date indicates, but does not prove, the contrary. Chernobyl notwithstanding, most of the problems of nuclear power worldwide have been problems concerning the people using the technology, not problems of hardware. The usual experience of developing countries is that they have difficulties mastering technologies much less demanding than nuclear technologies. Further, nuclear power has shown that it is horribly punishing to those who use it carelessly, but beneficial to those who devote the compulsive attention to detail required for success. Thus, it is essential to have a profound industrial "safety culture" in any country using nuclear power.

In considering this problem, it is important to distinguish between the task of creating a cadre of experts intellectually prepared to understand, and even advance nuclear technologies, from that of creating the human and physical infrastructure needed to use these technologies involving many people lacking an engineering education routinely at an industrial scale. The former is feasible for many countries, as is shown by numerous current programs to develop nuclear weapons. The latter is needed if nuclear power is to be an important energy source within a country. It depends far more upon cultural than intellectual factors. Most of the world's countries do not achieve a high standard of performance in industrial, or even transportation safety. Thus, it appears to be unjustifiably optimistic to expect this to be done in the much more demanding field of nuclear power. Doing a good nuclear job is daunting enough within the industrialized countries. Success appears to be improbable in less prepared countries.

None of this discussion proves anything. Rather, it is intended to draw attention to a practical factor which has been crucially important for nuclear power in the past, and which promises to remain so. Alternative arrangements to a worldwide nuclear deployment include producing hydrogen in the developed countries for shipment worldwide, and using foreign expert crews to operate nuclear facilities within developing countries. Each alternative is feasible, but would also have drawbacks until the country of interest becomes sufficiently competent.

SUMMARY

It is seen that serious barriers to use of nuclear power to mitigate global warming exist in the areas of nuclear energy forms, uranium resource limitations, current technology development directions and difficulties in deploying nuclear power plants worldwide. Conceivably the barriers can be overcome, but doing so would require an imaginative and ambitious program of technological research and development. Finally, the technologies produced would have to be easy to use, safe and economically attractive. The latter would require being more competitive than solar-based and geothermal energy technologies. It is too early to know what all of these requirements mean in practical terms, or whether a global warming response will be needed. However, if it is required, both the needed effort and the rewards of success will be great.

REFERENCES

Edmonds, J. and J. Reilly (1986). *The IEA/ORAU Long-Term Global Energy-CO_2 Model: Personal Computer Version A84PC*. Institute for Energy Analysis, Oak Ridge Associated Universities, ORNL/CDIC-16, CMP-002/PC, Washington, DC.

OECD (1992). *Uranium – 1991 Resources, Production and Demand.* A joint report by the OECD Nuclear Energy Agency and the IAEA. Paris.

Schenler, W.W. and M.W. Golay (1992). Interim report on ORNL/MIT technical support tasks for USDOE/MIT-NE integral fast reactor program – Task 2, environmental impact assessment; Martin Marietta Energy Systems, Inc. MIT report #MIT-ANP-TR-012, Cambridge, MA.