ADVANCED NUCLEAR POWER OPTIONS:

THE DRIVING FORCES AND THEIR RESULTS

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ABSTRACT

Successful nuclear power plant concepts must simultaneously demonstrate satisfactory performance in terms of both safety and economics. In order to be attractive to both electric utility companies and the public, such plants must produce economical electric energy consistent with a level of safety which is acceptable to both the public and the plant owner. Programs for reactor development worldwide can be classified according to whether the reactor concept pursues improved safety or improved economic performance as the primary objective. When improved safety is the primary goal, safety enters the solution of the design problem as a constraint which restricts the set of allowed solutions. Conversely, when improved economic performance is the primary goal it is allowed to be pursued only to an extent which is compatible with stringent safety requirements.

The three major reactor coolants under consideration for future advanced reactor use are water, helium and sodium. Reactor development programs focused upon safety and upon economics using each coolant are being pursued worldwide. These programs are summarized in Table 1.1. It is seen that the safety-oriented concepts are typically of lower capacity, by approximately an order of magnitude, than the economics-oriented concepts. This is the result, in the former concept, of using less efficient, but more reliable, means of accomplishing essential safety functions.

DIRECTIONS IN ADVANCED REACTOR TECHNOLOGY

The purpose of this paper is to examine the directions being pursued in nuclear reactor technology development worldwide. Current reactor development programs are categorized according to whether they are primarily concerned with enhanced economic performance or improved safety, while recognizing that both factors must be addressed satisfactorily in any concept.

Different societies disagree concerning acceptable levels of safety and the correct emphasis of good economic performance. There are three major categories of countries in terms of nuclear power development. The major (but not exclusive) emphasis of development in each category is as follows:

- Improved safety (Federal Republic of Germany, Sweden, United Kingdom, United States)
- Improved economic performance (Federal Republic of Germany, Canada, France, Japan, United Kingdom, United States)
- Attempting to emphasize both safety and economics (the United States).

Table 1.1

WORLDWIDE PROGRAM OF
NUCLEAR POWER TECHNOLOGY DEVELOPMENT

PROGRAM EMPHASIZING PASSIVE SAFETY

Federal Republic of Germany

- 100MWe Modular HTGR (Siemens, Brown Boveri)

United Kingdom and United States

- 300MWe Modular PWR (SIR Concept) (Rolls Royce & ABB-Combustion Engineering)

United States

- 130MWe Modular HTGR (General Atomic)
- 130MWe Modular LMR (PRISM Concept, General Electric)
- 750MWe PIUS-BWR (Oak Ridge National Laboratory)
- 600MWe LWRs (Semi-Passive Safety)
  - ASBWR (BWR, General Electric)
  - AP-600 (PWR, Westinghouse)

Sweden

- 500MWe PIUS-PWR (ASEA-Brown Boveri)

PROGRAMS EMPHASIZING ECONOMIC PERFORMANCE

Europe

- Joint European Fast Reactor (France, Germany, United Kingdom)
- European 1400MWe PWR (Nuclear Power International: France, Germany

Canada

- 450MWe HWR (CANDU 3) (AECL)
- 900MWe HWR (AECL & Ontario Hydro)

France

- 1400MWe PWR (N4 Project, Framatome, Electricité de France)
- 1200-1450MWe LMR (Superphenix-1 Project, Novatome, Electricité de France)

Federal Republic of Germany

- 500MWe HTGR (Successor to 300MWe THTR Project)
- 300MWe LMR (SNR 300 LMFBR Project)

Table 1.1 (continued)

Japan

- 1350MWe LWRs
  - ABWR (Tokyo Electric Power, General Electric, Toshiba, Hitachi)
  - APWR (Kansai Electric, Mitsubishi, Westinghouse)
- 714MWt LMR (Monju LMFBR Project)
- Successor to 148MWe FUGEN LWR/HWR Project

United Kingdom

- 1000-1400MWe PWR (Sizewell-B, Hinkley Point-C Projects)

United States

- LWR Requirements Document Project (Electric Power Research Institute)
- 1250MWe ABWR (General Electric)
- 1250MWe APWR (Westinghouse)
- System 80+ (ABB-Combustion Engineering)

Soviet Union

- Emphasis upon Passive Safety
  - Chernobyl-Type RBMK Reactor Series Discontinued)
- Emphasis upon Economic Performance
  - 950MWe PWR
  - 1250MWe LMR (LMFBR Type)

ABBREVIATIONS

BWR:	Boiling Water Reactor
CANDU:	Canadian Deuterium Uranium, Heavy Water Reactor
HTGR:	High Temperature Gas-Cooled Reactor
HWR:	Heavy Water Reactor
LMFBR:	Liquid Metal-Cooled Fast Breeder Reactor (version of LMR)
LMR:	Liquid Metal-Cooled Reactor
LWR:	Light Water Reactor
PIUS:	Process Inherent Ultimately Safe (version of LWR)
PRISM:	Power Reactor Inherent Safe Modular (version of LMR)
PWR:	Pressurized Water Reactor
SIR:	Safe Integral Reactor (version of LWR)

Depending upon national priorities and values the emphases of reactor development programs may differ greatly from one country to another. In most cases the priorities of these programs do not reflect specific concerns with alleviation of environmental problems such as those of global warming. Rather, they are focused upon nearer-term issues of public acceptance (in the case of passive safety) and economic benefits. The three major reactor types differ according to the fluids used for heat removal. The categories are light water reactors (LWRs, cooled by water), gas-cooled reactors (GCRs, cooled by helium) and liquid metal-cooled reactors (LMRs, cooled by sodium). Heavy water-cooled reactors are also produced in Canada and have been sold elsewhere.

Passive Safety

Protection of the public, or attainment of nuclear safety, requires retention from the biosphere of the radioactive material which is created within the reactor fuel during the fission process. The successive primary means of doing this are the following:

- Maintain the integrity of the reactor fuel
- Capture escaped radioactive materials within the reactor coolant system
- Capture escaped radioactive materials within a containment or confinement building.

The main threat to reactor fuel integrity arises from overheating, when the heat of radioactive decay within the fuel is not removed adequately. In a nuclear power plant, passive safety features are those which perform a safety function (e.g., reactor cooling) only using sources of motive force found in nature (e.g., gravity, radiative heat transfer). The interest in passive safety features is that they promise to be much more reliable than those using active components--man-made sources of motive power (e.g., pumps).

Use of passive safety features offers the greatest potential for reaching the greatest levels of safety attainable with a reactor concept. However, this is usually possible only at the expense of economic performance. This is because passive safety features typically are more reliable, but less effective than those using active components in accomplishing a particular function (e.g., flow of a coolant involving natural convection is typically slower and less controllable than pump-driven flow). Often the only way to accommodate such reduced effectiveness is to reduce the power of the reactor. Doing this increases both the capital and operating expense portions of the costs of electric energy.

An important aspect of passive reactor cooling is use of lower power levels than is typical in the economic-performance oriented concepts. This imposes capital cost disadvantages upon the passively safe concepts which must be overcome if they are to be employed. For example, to save money some of the proposed reactor concepts using passive safety features would be built without a containment building (e.g., the PIUS and MHTGR). The justification provided is that a containment would be unnecessary since the probability of fuel-damage should be very low. This argument will be examined very carefully in light of the experience of the Three Mile Island and Chernobyl reactor accidents. Both reactors sustained substantial core damage, but the former--which had a containment--caused no public injuries, while the latter--which had no containment--caused many injuries.

The United States is pursuing different major nuclear power development programs focused alternatively upon safety and economics. These parallel emphases reflect the divisions of opinion in United States society regarding the value, and required level of safety of nuclear power. The Federal Republic of Germany also has a dual emphasis in its programs. Sweden has an exclusive emphasis upon passive safety as the theme of its future nuclear power program. It has also adopted a phased moratorium upon future use of nuclear. Other countries having adopted nuclear power moratoria are Italy and Switzerland. Italian organizations are actively involved in the reactor development programs of Sweden and the United States emphasizing use of passive safety features. Swiss organizations have no such involvement. The United States has had an effective moratorium on new plants since 1974.

Concerns among the public over the level of safety achieved with the current generation of nuclear power stations have motivated reactor designers to improve their new concepts greatly. Concepts using passive safety features exclusively (termed passively safe reactors) involving all three major classes of reactors have been invented and are being developed. A passively safe concept provides the reactor cooling function without the intervention of an "active" system (e.g., a human action or an action by a device such as a pump or valve which must change its state).

<u>LWRs using passive safety features exclusively</u>: The PIUS (Process Inherent Ultimately Safe) concept is a LWR which keeps the reactor immersed in water under a broad range of possible accident situations. It does this by immersing the reactor and its coolant system in a large pressurized tank. The dense water in the tank contains a neutron-absorbing salt and is in contact with the less dense reactor coolant at two stratified fluid interfaces. If the flow of coolant should become disturbed, water from the tank will be introduced into the reactor, thereby shutting it down and providing sustained cooling. It promises automatic stability without human intervention for about a week.

<u>Modular HTGRs using passive safety features exclusively</u>: The modular high temperature gas-cooled reactor (MHTGR) concepts emphasize maintenance of fuel integrity by using fuel which is unusually robust at high temperatures. By limiting the power of the reactor the fuel can be expected to remain intact even when the available means of cooling are highly impaired. This is done utilizing natural convection of atmospheric air about the reactor vessel, or – failing that – radiative heat transfer from the reactor to its surroundings. The reactor is typically able to produce 150MWe.

<u>Modular LMRs using passive safety features exclusively</u>: Versions of LMRs using passive safety features exclusively rely less upon thermal toughness of the fuel than upon providing highly-reliable natural convection of the reactor coolant to a heat sink in order to cool the fuel. They also utilize natural convection of air around the reactor vessel and thermal radiation from the reactor vessel to the surroundings to cool the core. The reactor is typically able to produce 150MWe.

Semi-Passive Safety

In a variation upon the theme of passive safety two LWR concepts utilizing a blend of passive and active safety features are being pursued in the United States. These concepts could be termed semi-passively safe. A semi-passive system involves a small number of "active" components, but in a way which will be very reliable (e.g., by requiring very small energetic stimuli in order to activate the system). A BWR (the SBWR) and a PWR (the AP-600) of 600MWe each are designed to provide assured core cooling, but using typically one valve realignment in order to do so. By doing this, some of the economic penalties of the purely passive designs are avoided. It is expected that the marginal detrimental effects upon safety of this design approach are small compared to that of exclusive reliance upon passive safety features. The semi-passively safe reactors' proponents hope that any such detriments will be counterbalanced by significant economic improvements compared to the purely passively safe concepts.

Economic Performance

In most countries worldwide interest remains focused upon economic performance-oriented designs. These mainly concern LWRs and LMRs.

LWRs: With LWRs concerns for evolutionary improvements in both economics and safety are evident. Efforts for future improvements are focused in areas of economic performance which were considered to be of low concern when the current generation of plants was designed. Among the more important are improving plant operational availability and shortening the plant construction duration. Important LWR evolutionary improvement programs are being pursued in France, Germany, Japan and the United States.

LMRs: With LMRs outside the United States the universal concern remains that of designing highly efficient breeder reactors, which convert non-fissile U-238 into fissile Pu-239. Many countries have such programs. In most countries this concern is driven by a lack of nuclear fuel resources. The United States is the only country with a LMR program which is not focused upon breeding as the primary objective. In all of the LMR countries listed in Table 1.1, the programs have been in place for many years and are at the stage of gaining experience through operation of small prototype reactors. The largest such reactor is the 1200MWe Superphenix in France. Over time scales greater than a century the ability of nuclear fission to contribute to alleviation of global warming will depend greatly upon efficient use of nuclear fuel resources. This would require use of breeder reactors. From this perspective the primary focus of the United States' LMR program upon passive safety is seen to be a preoccupation with near-term issues, mainly that of public acceptance of nuclear technology.

HWRs: In Canada a design for an evolutionary CANDU of 450MWe has recently been offered. Otherwise the focus remains upon an evolutionary concept of about 900MWe capacity.

The Soviet Union

The Soviet Union has been the only Communist country with a reactor development program. Until the Chernobyl accident in 1986 the Soviet Union had been focused upon economic performance with its reactors. Since then development priorities have appeared to be ambiguous. Development of new Chernobyl-type RBMK reactor concepts has ceased. However, development of improved, economic performance-oriented PWR and LMR concepts continues. During 1988, agreement was reached to build a passively-safe 100MWe HTGR of West German design and manufacture. This project has since been abandoned due to financial constraints, but its initiation may indicate a major change in the orientation of the Soviet development program.

Since the Soviet Union has been a major nuclear power station supplier to Eastern European and third world countries such a change could have a major effect upon future versions of nuclear power technology. However, the uncertainty which has lately characterized the Soviet Union makes it difficult to guess what directions reactor development work might take.

CRITIQUE OF ALTERNATIVE REACTOR DEVELOPMENT STRATEGIES

Safety Performance

The functions essential for ensuring reactor safety are summarized in Table 1.2. It is seen upon examination of the passively and semi-passively safe reactor concepts that they perform the function of post-shutdown reactor cooling by means of thermal conduction, natural convection and thermal radiation, while the economically-oriented concepts rely upon active systems (including humans who can be highly stressed during the response to an accident). The MHTGR concept uses a confinement structure for performing the functions of capturing but not of containing material released from the core during severe accidents. In the PRISM version of the LMR concept, radioactive materials can be trapped in the reactor coolant, and a containment shell is used. The semi-passively safe LWRs use a quenching tank for capturing radioactive materials leaving the reactor coolant system.

Table 1.2

SAFETY PERFORMANCE IMPROVEMENT

ESSENTIAL SAFETY FUNCTIONS

- Stable Operation
  - Achieve High Mechanical Operational Reliability
    - o Minimize number of system failure modes and interdependencies
    - o Maximize component reliabilities
  - Achieve High Human Operational Reliabilities
    - o Provide extensive instrumentation and computer-aided information assessment to operators
    - o Automate tasks difficult for humans
    - o Design for easy operations, troubleshooting and response to unexpected events
- Reliable Shutdown
  - Design for Passive Negative Reactivity Feedback in Core
  - Provide Diverse, Redundant, Passive Shutdown Systems
- Reliable Reactor Cooling
  - Use Natural Convection to Pump Coolant from the Reactor to a Heat Sink
  - Conduct and Radiate Heat from the Reactor to a Heat Sink
- Reliable Containment of Radioactive Materials
  - Trap Materials in Filters, Pools, Sprays and On Exposed Surfaces
  - Retain Materials within Fuel, Reactor Coolant System and/or Containment Building

All LWR concepts use a containment building. The semi-passively safe systems use natural convection and evaporative cooling to prevent containment over-pressurization, and the evolutionary plants use active systems for this purpose. Thus, the different reactor concepts use a variety of combinations of means for assuring protection of the public. The absence of a containment building in the MHTGR concept is a cause for concern in view of practical experience and a host of LWR risk analyses which indicate the great potential value of such a safety feature. The inability of LWR materials to sustain temperatures as great as those of the MHTGR and LMR causes concern with that concept.

Each reactor concept has unlikely but serious potential accident modes, including those involving human error. At this point no concept has been developed to the point that definitive comparisons of expected safety performance can be made. It can be argued that each reactor concept has substantial promise, but for differing reasons. The faults of the LWRs are much better known than are those of the others. However, the experience records of reactors using each of the major coolants is mixed, with both successes and failures being conspicuous with each. Consequently, it is difficult to infer from past performance the expected future performance of various reactor concepts, particularly when they are at their current states of immaturity.

The ultimate success of a nuclear power plant depends upon a combination of the following elements:

- The basic nuclear power plant concept, including means for reducing risks created by mechanical failures and by human actions (notably the most serious nuclear power plant accidents have featured important human errors);

- The detailed nuclear power plant design, based upon the plant concept (mechanical failures in nuclear power plants are more a consequence of faulty detailed design decisions or fabrication errors than of faults in the basic concept, for example the flagship of the West German HTGR program, the THTR 300 was recently shut down permanently due to failure of the core support structures within the reactor vessel);

- The management of the plant (e.g., the history of LWRs shows broad variations in the ability of different organizations worldwide to utilize essentially similar hardware).

The passively safe reactor concepts all attempt to decrease expected public risks by minimizing the unavailability due to mechanical failures of systems needed to perform essential safety functions. With care in the execution of the concepts now available it is reasonable to expect that significant improvements can be made in safety system reliability. However, corresponding gains in reducing the unavailability of safety systems due to human actions are less assured. The major advances made have involved eliminating human actions in accident response. However, safety vulnerabilities due to errors in manufacturing, fabrication, maintenance, operational mode switching and needless intervention can be very subtle and difficult to eliminate. It is not clear that significant improvements have been made in such areas.

Thus, the additional expected contribution to total safety system unavailability due to human actions with all of these concepts remains unknown. Such contributions are difficult to anticipate when concept development has not advanced to the stage where detailed system designs and plant operational procedures can be defined. Thus, at this point it is impossible to state that a particular concept is superior to another in terms of safety. However, it is reasonable to expect improved safety performance for the passively safe concepts if care is taken through the design detail and procedure creation stages of project evolution.

History to-date has shown that unbalanced focus upon only a portion of the problems of designing and operating nuclear power plants is an invitation to disappointment. In the United States public discussion of passively- and semi-passively safe reactors, through the competition of their various proponents for public funds, has focused upon the optimistic hopes for each concept for improved safety. However, the uncertainties of these hopes, the difficulties to translating a concept into a successful design and the ability of even the most perfect hardware to be ruined through thoughtless use have largely been glossed over. These factors are reasons not for pessimism, but for caution, in public debate. Nuclear power plant technologies deployed to-date have been seriously unforgiving of careless operations. However, the great majority of such plants in current use have performed very well. It is reasonable, but not assured, with any of the reactor concepts being developed currently, to expect that we can do better in the future, by learning from past experience.

Economic Performance

Within the United States dissatisfaction with the economic performance of the current (LWR) nuclear power plants has arisen more from the wide variation of capital costs (by a factor of approximately three) of such plants than from their having been expensive on average. For the economically-oriented concepts, the uncertainty and impracticability of the economics of a project, particularly through the actions of the NRC and state public utility commissions (PUCs), remain as deterrents to investors to becoming involved in future nuclear power plant projects. Whether such uncertainty will obtain in the future is impossible to know. However, the burden rests upon any reactor concept to assure that the uncertainties of future costs will be small.

In addition to high capital costs, unexpectedly low average operational availability and high operating and maintenance costs have also discouraged some U.S. utilities. It is notable that the economic performance of the best United States LWRs is as good as found elsewhere. However, the broad variation in all aspects of performance is unique to the U.S. Since the hardware is common worldwide, this suggests that the way in which nuclear power affairs are conducted may explain more of the United States experience than does the technology. Notably, in most other countries which have also relied upon LWR technology the level of satisfaction has been higher than in the United States. This fact is reflected in the vigor of reactor development programs focused upon evolutionary concepts.

The great challenge to the passively and semi-passively safe concepts is to be economically competitive with larger reactors and other electricity technologies. The economies of scale favor larger power plants. The main proposal for achieving competitive economic performance with the small passively safe concepts is to employ factory-fabrication of a large portion of the power plant. The modules produced would be shipped to the station site for integration into a complete power plant. These reactor modules would then be operated from a central control station. It is argued that improvements in work quality and construction scheduling could be sufficient to make the modular passively safe concepts economically attractive.

It is hoped by proponents of the small reactor concepts that these economies could offset those of scale. However, no evidence is currently available to justify confidence that they will do so. Major challenges to successful factory fabrication exist in the areas of financing such factories and in coordinating the markets for their products so that potential economies of serial production may actually be realized. These problems are not reasons to refrain from developing the passively safe concepts. However, they are reasons to temper premature optimism concerning the ultimate success of these concepts.

PUBLIC AND UTILITY ACCEPTANCE OF FUTURE NUCLEAR POWER TECHNOLOGIES

Historically technologies thought by the public to be dangerous have become accepted only through establishment of a sustained record of sufficiently trouble-free operations, not through arguments by their proponents or by authority figures that they were safe. What constitutes a sufficiently trouble-free record of operations has usually depended upon the level of benefits associated with the technology (e.g., the public has been willing to tolerate a certain frequency of fatalities in order to gain the convenience of air travel). Nuclear power has not yet established a record of trouble-free operations, or a perception of substantial public benefit. Consequently, the quality of operations demanded for public acceptance has been very stringent. This situation could change rapidly if public consensus were to accord nuclear power a desirable status (e.g., for alleviating global warming or as a means of weaning the country from coal or oil (e.g., via electrical transportation)). However, in the absence of such an appreciation it may not happen that the public will be inclined to consider intellectual arguments (e.g., through experimental demonstrations and validation by experts) that a new nuclear power technology is safe. History offers no examples where such an approach at gaining public acceptance has been successful. Thus, the expectation of many proponents of passively safe reactors that things will be different this time may lead to disappointment.

The importance of an accident-free record of nuclear power plant operations worldwide is obvious. It has motivated establishment of the Institute for Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO), and is of concern to all who are involved in advanced reactor development. However, it is unclear whether INPO and the NRC have the ability to obtain the needed performance from every United States utility. Similarly, the ability of WANO and the International Atomic Energy Agency (IAEA) to be correspondingly effective worldwide remains an open question. Limitations in each of these organizations provide the potential for future utility performance to fail to meet the stringent standards of the highly distrustful public. Also, future core-damage accidents worldwide are much less likely than a decade ago, but are still not inconceivable. Such events could be very injurious to the future deployment of advanced reactor technologies, and constitute one of the most important perils for that enterprise.

The different advanced reactor concepts have substantial promise, but each for a differing set of reasons. There are many problems inherent in taking an idea to the stage of practical use. It is prudent to recognize them all from the beginning, and to plan to solve them. There is no reason to doubt that this can be done with the concepts being pursued currently. But there is also no basis for thinking that current efforts are sufficient to justify confidence of success. In an uncertain world it is difficult to know which options being pursued today are likely to remain valuable tomorrow. For that reason diversity and vigor should characterize international advanced reactor development programs.

In addition, in the United States the timely ability to deploy any advanced reactor is highly uncertain because the Nuclear Regulatory Commission (NRC) is proceeding slowly with the review of advanced reactor concepts, and appears to be having great difficulty in creating an intellectually consistent approach to safety regulation. This is important worldwide because of the influence which the NRC retains upon the safety policies of many other countries. Current NRC regulations are a patchwork of rules which was created as the safety concerns of the current LWRs became understood. The fact that the current approach to regulation is not suitable for advanced reactors has been noted for several years. However, the NRC has made little real progress in creating an alternative regulatory approach. As with the existing reactors, the uncertainties injected into advanced reactor development by the unpredictability and slowness of future NRC actions may ultimately still such development. If this were to occur it would be a particular tragedy because a goal of the safety-oriented reactor concepts is improved safety. It could occur that the conservatism of the NRC could greatly inhibit safety gains which are within reach.

PROSPECTS FOR THE FUTURE

The most heavily funded programs of reactor innovation are those of Japan and France, both of which have resulted in actual nuclear power plant projects. In the United States the programs on passive and semi-passive safety – addressing one MHTGR, one LMR and two LWR concepts – are inadequately funded, being in total at about the level needed to bring a single concept to maturity.

The countries having safety-oriented reactor development programs, Italy (as a participant in the programs of other countries), Sweden and the United States, have all had experiences of severe nuclear power controversy. The main country subjected to sustained nuclear controversy which has not initiated a safety-oriented concept development program is the Federal Republic of Germany. Interviews in Germany indicate the judgement that public acceptance there cannot be achieved through novel technological offerings. In countries where the nuclear power experience has been less controversial (e.g., Canada, France, Japan), the reactor technology development strategy has been to continue evolutionary development of large LWRs and LMRs and CANDUs.

Prospects for future nuclear technology deployment in different countries are unique to each country. Important factors affecting the acceptability of such deployment include:

- The degree to which nuclear power is viewed as being beneficial (e.g., in economic, strategic, environmental and safety terms),
- The degree to which nuclear power operations, locally and worldwide, have been free of trouble,
- The degree to which political institutions permit a determined minority to increase the costs of nuclear power projects.

Nuclear technology innovation by itself is not listed among such factors. Rather, it affects technological acceptability as an element which can influence the factors listed above. For example, technologies offering increased safety are claimed to be able to garner increased public acceptance, assist improved operations and reduce opposition to future projects.

The main danger to development of comprehensively satisfactory new technology is incomplete thinking. Good performance in terms of safety and economics requires satisfaction of a set of goals (e.g., high reliability) each of which contributes to overall performance. Technology advancement often proceeds by focusing resources upon improvements in a few areas (e.g., severe accident safety) while ignoring others (e.g., human errors). The result of such unbalanced progress can sometimes be improvements in some high-priority areas (e.g., public acceptance) with little improvement in the overall costs of electric energy or expected risks. The challenge in advancing nuclear power technologies is to maintain progress on many fronts, while avoiding over-emphasis upon only a few issues, such as those which have lately been in the news.

Both the economically-oriented and safety-oriented nuclear power plant concepts are attempting to gain sufficient acceptance from both the public and utilities that they may be employed in the future. However, their rationales differ substantially. The goal of the economically-oriented nuclear power plant concepts is to gain utility acceptance, while attempting to satisfy a level of safety which would make serious reactor accidents very infrequent. The goal of the safety-oriented nuclear power plant concepts is to gain public acceptance essentially by means of intellectual arguments. It is worth considering that neither strategy may be successful, as each may be too unrealistically simplistic. Rather, a more comprehensive development strategy which recognizes that things must go right in many ways in order for nuclear power to be successful may offer greater chances for ultimate future acceptance.