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Standardization of Nuclear Power Plants in the U.S.

A Report by the Study Group
on the Practical Application of
Standardized Nuclear Power Plants
in the United States

November 1986

Atomic Industrial Forum, Inc.
7101 Wisconsin Avenue
Bethesda, MD 20814-4891

EXECUTIVE SUMMARY

This report describes the findings of the Study Group on the Practical Application of Standardized Nuclear Power Plants in the United States* The group was established by the AIF in March 1985 with members representing a broad spectrum from the nuclear industry. The objectives of the Study Group were to determine the practical benefits of standardizing commercial nuclear power plants in the United States and the actions needed to make standardization a reality.

The report also includes a description of the French civilian nuclear power program and highlights some areas for comparison with American practices. This information was gathered during a trip to France by some Study Group members.

The Study Group believes that nuclear power is a crucial component of electric power supply in the United States and that standardization would provide a major stimulus to the revitalization of the nuclear option. To encourage the further development of standardized nuclear plants, the Study Group also believes that the current licensing process is no longer appropriate and that it needs to be modified substantially. For this reason, it endorses legislative proposals supporting standardization and regulatory reform. Such proposals would facilitate the use of preapproved sites and the development and use of standardized designs, would provide for the issuance of a construction and operating license (COL), and would improve regulatory stability. In particular, the one-step licensing process would give licensees greater assurance that if a facility is constructed in accordance with the terms of its COL it will be permitted to operate once construction is complete without the possibility, as under the present system, that operation of a completed plant may be postponed indefinitely.

The Study Group developed a Position Paper on Standardization with a comprehensive description of the policies and actions that it urges the Nuclear Regulatory Commission (NRC) to take. This paper was sent to the NRC on March 20, 1986. In this paper, the Study Group indicates that consistent with, and in direct support of the proposed statutory changes, the NRC must change its policies and regulations in a manner that will provide the necessary stability and predictability to the licensing process, and incentives for standardization. Both a Congressional mandate and the actions described in the position paper are considered necessary to accomplish the maximum benefits regarding standardization.

In particular, the Study Group supports the granting of Design Certifications (DC). DCs in the form of NRC rules would not be subject to challenge in individual licensing hearings and are expected to, ultimately, become the standardization option most favored by the industry.

The recommended licensing process would require a final determination by the NRC that construction and operation of a preapproved reference design will provide the required assurances of adequate health and safety. Such determination would be made before construction is started. Therefore, applications for DCs and COLs will need to include all the information necessary to define and characterize properly the construction and operation of the designs. The Study Group developed a detailed description of the design information and applicable inspections, tests, analyses, and their acceptance criteria that would need to be provided to support a DC or COL application, and offered to the NRC the assistance of experienced industry groups in the development of more detailed guidance.

The recommended licensing process would also allow for a more effective means of public participation by holding hearings based on essentially complete designs before construction is started and when it is feasible to make changes in the design in an efficient manner. This is in contrast to the current process where hearings are held either when only preliminary design information is available or after the facility has been built and changes are either not feasible or cannot be accommodated without significant impacts on cost and schedules. Only new issues that could potentially affect the safe operation of the plants and that meet specified threshold criteria could be raised after the plants have been built and prior to their operation.

In addition to the large up-front investments needed to prepare the DC and COL applications, the development of new standardized nuclear power plants will require rigorous commitments to quality assurance programs, adherence to construction schedules, avoidance of customized changes, and overall high standards in the construction and operation of the plants.

*Appendix F is a list of the members of the Study Group

The use of preapproved standardized designs in conjunction with one-step licensing and the other improvements described in this report would result in substantial cost reductions. The report includes the results of some illustrative cost studies performed by the Study Group. These studies show that the most significant cost reductions would be attained as a result of a shortened construction schedule and from the amortization of the design among several buyers. The availability of design details prior to construction would also lower costs by allowing for more efficient construction practices, higher construction productivity, and the use of modularization. Standardization would further lower costs through expedited licensing reviews and more efficient personnel training, maintenance procedures, spare parts programs, and overall plant operations.

The savings in overnight and time dependent costs are estimated to result in a cost reduction of over 55% for a standardized plant as compared to a plant using 1985 best cost experience. As a result, such a standardized plant authorized in 1986 could be built for an estimated $1186 per kilowatt in current (as spent) dollars coming on line in 1992, as compared to $2650 per kilowatt in current (as spent) dollars for a plant authorized in 1986 using 1985 best cost experience. Further cost reductions could be achieved by reducing the construction schedule to 60 months and shorter, as has been achieved in other countries and in the United States in the 1960s and early 1970s.

To achieve these cost savings, the analysis assumed an n^{th} plant in a family of plants taking credit for series procurement, the construction learning curve and modularization. Good management was assumed for all phases of design and construction in a stable regulatory environment.

If a standardization program had been in place in the United States in 1980, an n^{th} nuclear power plant authorized at that time would have reached commercial operation in 1986 at a capital cost of $932 per kw *(assuming the same factors applied as were used in this analysis).* With a 70% capacity factor, this relates to first year capital costs of 3.2¢ per kwh (2.4¢ per kwh levelized over 30 years). If the current operation and maintenance costs of 0.9¢ per kwh, fuel costs of 0.6¢ per kwh and other costs of 0.1¢ per kwh are added to these capital costs, total first year generation costs for the plant would be under 5¢ per kwh (under 4.0¢ levelized over 30 years). This 1986 cost of electricity from a standardized nuclear power plant, such as described in this analysis, is believed to be competitive with, or cheaper than, any other energy resource for providing new electric generating capacity.

The estimated cost savings, together with potential alternative organizational arrangements for building and operating future plants, innovative financing and risk sharing approaches, and more predictable working relationships with public utility commissions would provide the basis for a healthy nuclear industry.

I. INTRODUCTION

This report describes the findings of the Study Group on the Practical Application of Standardized Nuclear Power Plants in the United States. The group was established by the AIF in March 1985 with members representing a broad spectrum from the nuclear industry — vendors, AEs and constructors, utilities, legal interests, and other industry organizations. The charter of the Study Group was to define the actions needed for the effective implementation of standardization, and to determine the practical benefits of standardization, mainly with regard to safety, operations and cost.

Nuclear power is a significant and growing component of power supply both in the United States and throughout the world. During 1985, more than 370 nuclear generating units, with a total generating capacity of 248 million kilowatts, provided about 15 percent of the world's electricity. Nuclear power is now the second largest source of electricity in the United States. It passed oil as a source of electricity in 1980, natural gas in 1983, and hydropower in 1984. Only coal provides more of the nation's electricity.

More than 100 nuclear power plants are now licensed for operation in the United States. Their total generating capacity is more than 88,000 megawatts (as of October 1986), and they provide over 16 percent of the nation's electric power. In four states (Vermont, Maine, Connecticut, and South Carolina) nuclear power provides more than 50 percent of of the total electricity generated. Six other states receive more than 30 percent of their electricity from nuclear plants.

Nuclear power in the United States has saved the equivalent of burning more than 5.6 billion barrels of oil. In the past decade nuclear power has saved consumers between $36 and $63 billion, when compared to the electricity generated by oil or coal that they would otherwise have consumed, and these savings are continuing to accumulate.

With the economy expanding and demand for electricity on the rise, utilities are now planning for new generating capacity that will be needed in the 1990s and beyond. Only two domestic energy resources can be counted on to meet the expected base load electricity demand requirements for the foreseeable future: coal and nuclear. Unfortunately, from a business perspective, nuclear power is often perceived by the utilities and the financial community as a risky investment, owing to the large and uncertain capital requirements long lead times needed to license and construct a plant, and difficulties in including the costs in the rate base.

Nuclear energy, however, should not be considered an "option" which this country can afford to lose; instead it should be considered "essential." The national security, economic and environmental risks of a future United States society with only coal as the major long term domestic fuel for base load electricity generation are far too great to allow nuclear energy to disappear as a domestic energy resource. This was recognized in the recently issued National Energy Policy Plan V, where the Administration highlighted the value of a balanced energy mix and identified the revitalization of civilian nuclear power to be an important objective of national energy policy.

The nuclear industry has learned by experience that nuclear power plants can be built in a cost effective and successful manner through excellent management, adherence to quality assurance programs, and avoidance of rework. Based on this experience, we can anticipate that past errors will be avoided and that nuclear plants ordered in the future will be built at a lower cost than those completed recently. The Study Group believes that standardization will be a major component of the incentives necessary to make nuclear energy a viable option for the utility industry to meet future electricity demands. The standardization of the designs will provide further benefits and cost reductions. This belief is shared by leading members of the Administration, Congress, and the Nuclear Regulatory Commission (NRC).

A "standardized design" means a design for an entire nuclear power plant, a nuclear steam supply system (NSSS), the balance of plant (BOP), or a discrete subsystem which is reviewed and approved by the NRC, and can be reproduced from site to site and from utility to utility. Such preapproved designs can be relied upon by an owner to form the basis, or part of the basis, for an application to construct and operate a nuclear plant. In a program as large as that in the United States, standardization could allow a choice, at any point in time, from four or five preapproved designs.

Standardization would offer cost savings through shared engineering services, common specifications, use of envelope designs, construction and operation learning curve benefits, reduced schedules for multiple units, and management experience in the overall construction and operation of similar units. Foremost, standardization would increase the confidence of investors and rate payers that original cost estimates will not change drastically, that construction schedules will be maintained, and that the efficiency and safety of the plants will be further enhanced.

Standardized designs can benefit the public health and safety by concentrating the resources of designers, engineers and vendors on particular approaches, by stimulating standardized programs of construction practice and quality assurance, by improving the training of personnel, by fostering more effective maintenance and improved operations, and by enhancing the effectiveness of public participation. Standardization will also allow for a more expeditious and efficient review process and a more thorough understanding of the designs by the NRC staff.

Finally, standardization should be helpful in convincing state regulatory organizations that utilities should be allowed to recover fully their investments. In the past, the construction of nuclear power plants covered a wide range of experience — from plants built within their anticipated cost and schedules to plants that were cancelled after incurring substantial cost overruns. Standardization, together with management and budget controls and the commitment to build and operate the plants in the most effective and efficient manner, should narrow this range and bring all plants towards the "best plant" values. In view of the fact that even the best plants have been first-of-a-kind designs, standardization will be expected to further improve the performance and economic value of future plants. This should help the utilities in regaining the confidence of the state regulators.

II. STANDARDIZATION AND THE REGULATORY PROCESS

No nuclear plant has been ordered in the United States since 1978, and many of those ordered in the mid 1970s have been cancelled. There are three primary reasons for this situation: diminishing rate of increase in energy needs, excess generating capacity, and inordinate increases in the cost of the plants. Each of these is the result of many other complex and interrelated factors. For example, cost overruns have been caused by inefficient management and quality assurance practices, failure to maintain construction schedules, design changes and additions, the need for extensive rework, high inflation rates, and obstacles created by the regulatory process, among others.

Standardization is capable of providing a crucial stimulus to the nuclear industry. However, just as no single factor can be held solely responsible for the nuclear industry's difficulties, no single remedy will produce the necessary cure. The benefits of standardization cannot be realized without comprehensive changes in the regulatory process.

It is also necessary to recognize that the nuclear industry has matured sufficiently to become its own "first line" regulator. The accident at Three Mile Island underscored the importance of excellence in design, construction, and operation of nuclear power plants. Since then, the industry has taken aggressive steps to upgrade management, quality assurance, operator training, and other elements of nuclear plant operation. As a result, there is a renewed awareness by the industry and the NRC that the licensee is the one who is directly responsible for the safe operation of its facility and, therefore, is in the best position to determine how to achieve excellence in operations. This excellence will be achieved, not because of escalating regulatory requirements and their enforcement by a regulatory body, but rather by means of the financial and professional incentives which accrue when sights are set on excellence rather than on regulatory requirements.

The nuclear licensing process was established by the Atomic Energy Act of 1954 and is currently implemented by the NRC. According to this process, an applicant first submits to the NRC an application for a Construction Permit (CP). This application contains preliminary design information and must be subject to a public hearing following the conclusion of the staff review. The design is usually finalized in parallel with the construction of the plant. As the design and construction near completion, and many parts and components have been procured, delivered and installed, an application for an Operating License (OL) is submitted to the NRC. Before the OL is granted, the application is reviewed by the technical staff, and an additional opportunity for a public hearing is offered. This review and hearing cover not only the final design of the facility, but also the construction process, testing of installed equipment, quality assurance and control programs, proposed operating procedures, and conformance with regulatory changes since issuance of the CP. As the result of the second review and hearing, design modifications, additional reviews and inspections, and construction delays may occur just as the plant nears completion and the utility prepares to bring it into service and begin to recover its investment.

Based on past experience, it is the general belief of the nuclear industry that this licensing process needs to be substantially modified. It is an outmoded process that no longer leads to the efficient utilization of resources by the designers and regulatory bodies, does not promote optimum

designs or financial commitment to early design work, does not effectively focus on the proper safety issues, and has an inherent high level of uncertainty and instability.

A. Recommended Regulatory Changes

There are four legislative proposals addressing licensing reform currently pending in Congress.[1] Although there are differences among these bills, some of them preferable to others, all four share the same basic objectives with respect to standardization. The Study Group fully endorses these objectives. These proposals would facilitate the use of preapproved sites and the development and use of standardized designs, would provide for the issuance of construction and operating licenses (COL), and would improve regulatory stability.

The Study Group believes that these legislative changes are necessary to create an environment supportive of the development and deployment of nuclear power and to obtain the full benefits of standardization. In particular, the one-step licensing process would give the licensees greater assurance that if the facility is constructed in accordance with the terms of the COL it will be permitted to operate once construction is complete without the possibility, as under the present system, that operation of a completed plant may be postponed indefinitely. The Study Group also believes that independently, but in direct support of these legislative proposals, the NRC must change its policies and regulations in a manner that would encourage and support the development of standard designs in the U.S.

To this effect the Study Group developed a position paper with a comprehensive description of the policies and actions that it urges the NRC to take.[2] However, it cannot be overemphasized that both a Congressional mandate and the actions described in the position paper are necessary to accomplish the maximum benefits regarding standardization.

The position paper indicates that the preapproval of designs which can be referenced in individual plant applications, and in particular Design Certifications (DC), must be the cornerstone of the Commission's standardization policy. DCs in the form of rules approved by the Commission would be issued following the staff review, including the opportunity for public participation. DCs would then be conclusive on matters encompassed therein with regard to staff, ACRS, Commission and hearing board reviews of license applications, and cannot be subject to challenge in individual licensing hearings. The Study Group believes that, ultimately, certified designs will become the most favored by the industry in view of their substantial stability.

The position paper also urges the Commission to establish a comprehensive standardization policy by taking the following actions. First, standard design applications should be reviewed and approved expeditiously even in the absence of a reference application. Second, standardization will not be achieved if the reference designs are changed in an undisciplined manner or are rereviewed and backfitted after they have been approved. Accordingly, vigorous application of the backfit rule must be an integral part of the standardization policy. Further, the NRC staff should be directed not to rereview any feature of an approved standard design unless it determines, based on significant new information, that the design will not provide reasonable assurance of adequate protection of the public health and safety or of the common defense and security. Third, the Commission should assign a senior manager responsible to the Commission for the effective implementation of its standardization policy. Finally, the Commission should review and modify its regulations to provide that once construction and use of a standardized design have been authorized in a reference application after an opportunity for a hearing has been provided, licensing issues are not subject to further adjudication in the absence of good cause as defined by the Commission in its 1985 proposed legislation to the Congress.

The implementation of these recommendations would be a major step toward the establishment of a regulatory environment conducive to the development of standard designs and the submittal of new applications for nuclear power plants.

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[1] H.R. 1029 "Nuclear Power Plant Standardization Act of 1985." Broyhill-Hall, February 7, 1985.

S.836 (Simpson, April 2, 1985)/H.R. 1447 (Udall, March 6, 1985) "Nuclear Power Plant Licensing and Standardization Act of 1985." This is legislation proposed by the NRC.

S.2073 (McClure, February 18, 1986)/H.R. 2488 (Broyhill, May 14, 1985) "Nuclear Facility Standardization Act of 1985." This is legislation proposed by DOE.

H.R. 5448 "Omnibus Nuclear Safety Act of 1986." Bryant, August 15, 1986.

[2] "Position Paper on Standardization" by AIF Study Group on the Practical Application of Standardized Nuclear Power Plants in the United States, March 20, 1986. See Appendix A.

B. Implementation of Recommended Regulatory Changes

The proposed legislation and recommended Commission policy would require a final determination by the NRC that construction *and* operation of a preapproved reference design will provide adequate protection of the public health and safety and of the common defense and security. Such a determination would be made before construction is started, thus providing the necessary assurance that the design will not be arbitrarily changed during construction.

The Study Group believes that the NRC should prepare detailed guidance describing the level of information necessary to make the requisite safety findings, and the applicable inspections, tests, analyses, and acceptance criteria, and has offered the assistance of experienced industry groups to work with the staff on this endeavor. The design information contained in DC and COL applications would support equipment procurement and include qualification, installation, and testing procedures defining fully the requirements for implementation of the detailed design. However, name plate information would not be available.

Incorporation of this level of design information in a DC or COL application represents a significantly different method of design, construction, and regulation of nuclear power plants. In the past, design information of a preliminary nature was furnished on the front end of the licensing process leaving open the potential for significant changes during construction or at the OL stage. In the DC and COL process design engineering would be essentially complete, the regulatory requirements thoroughly defined, and public input incorporated before construction of the plant begins.

After the COL has been granted, a series of confirmatory sign-as-you-go audits will occur as the plant is built. These audits will assure that the plant is constructed consistent with the preapproved criteria and that the specified tests have been completed satisfactorily. Upon completion, the plant would be allowed to begin operation.

This process would also allow for a much more effective means of public participation by holding hearings based on essentially complete designs before construction is started and when it is feasible to make changes in the design in an efficient manner. This is in contrast to the current process where hearings are held either when only preliminary design information is available or after the facility has been built and changes are either not feasible or cannot be accomodated without significant impacts on cost and schedules. Only new issues that could potentially affect the safe operation of the plants and that meet specified threshold criteria could be raised after the plants have been built and prior to their operation.

However, for this process to take place, it is necessary that applications for DCs and COLs include all the information necessary to define and characterize properly the construction and operation of the designs. Development of such an application would require a large expenditure of capital (estimated at $150 to $200 million) by the designers. This is the price that the industry must pay to achieve the perceived benefits of standardization.

The importance of attaining stability in design requirements provides a powerful incentive to establish a regulatory framework that when combined with utility discipline offers a predictable licensing process. It is thus to the advantage of the industry to provide the large investment up front in exchange for a system that provides this stability and predictability. It is also to the advantage of the utility, in terms of construction efficiency and schedules, to maintain design well ahead of construction.

In addition to large up front investments, the standardized nuclear power plants will require rigorous commitments to standardized quality assurance programs, adherence to construction schedules, avoidance of customized changes, and overall high standards in the construction and operation of the plants.

A description of the detailed design information that would be needed to support a DC or COL application is included in Appendix B.

III. EFFECTS OF STANDARDIZATION ON THE COST OF NUCLEAR POWER

The capital costs needed to build a commercial nuclear power plant in the United States have risen tenfold in the last 20 years. It is believed that the use of preapproved standard designs in conjunction with one-step licensing and other regulatory changes, strict quality control, and adherence to construction schedules would result in lower and more stable costs.

The Study Group analyzed the effects of standardization on the different components to the cost of nuclear power plants based on data available from other countries. The results of these analyses are described in the report "Report on Standardization Cost Savings" (Appendix C).

The Study Group used the Energy Economic Data Base (EEDB VII) maintained by United Engineers and Constructors for the Department of Energy to develop a best cost experience model for comparison with an n^{th} plant model in a standardized series. The assumptions of a 1986 plant authorization date, plant size, financing and escalation were held constant for both models. In the comparison of the models used in the analysis, 82% of the cost savings are in the time related costs of escalation and financing. The only significant non-time related cost savings is the indirect cost of design and management services where 14% of the cost savings are achieved.

The combined savings in overnight and time dependent costs would result in an overall cost reduction of 55% for the standardized plant. As a result, such a standardized plant authorized in 1986 could be built for an estimated $1186 per kilowatt in as spent dollars coming on line in 1992, as compared to $2650 per kilowatt in as spent dollars for a plant using the best cost experience model. Further cost reductions could be achieved by more efficient construction processes that may be implemented in the future, and by further reductions in the construction schedule. Construction schedules of 60 months and shorter have been achieved in other countries and in the United States in the 1960s and early 1970s.

IV. OTHER CONSIDERATIONS AFFECTING THE REVITALIZATION OF NUCLEAR POWER

In conjunction with standardization, the Study Group considered other factors that may help minimize the financial risks faced by electricity generators when they commit to build new plants. In particular, the Study Group considered third party financing or owning of standardized nuclear power plants and other organizational models.

The rate regulatory environment is another major disincentive to the continued use of nuclear energy. Specifically, utility executives perceive that the rate establishment has in many instances adopted inconsistent policies toward nuclear projects. In the case where a nuclear project is consistently managed to the highest standards of excellence, resulting in considerable savings to ratepayers, the utility is often rewarded with only a marginal increase in its rate structure, with the bulk of the benefits going to the ratepayers. On the other hand, if the nuclear project runs into difficulties — regardless of whether the problems are outside the utility's control — the stockholders are often made to shoulder the bulk of the financial consequences. Where these conditions exist, it is unlikely that utilities will return to the nuclear market unless this risk benefit equation is balanced.

Accordingly, the Study Group assessed a number of organizational models which could have the potential to balance a nuclear project's benefit with its risks. Included were:

- Joint ventures;
- Shared risk arrangements, in which suppliers assume some measure of financial exposure;
- Generating companies under FERC regulation; and
- Deregulated generating companies.

The Study Group concluded that based on the benefits of standardization and regulatory reform, and assuming that appropriate up-front agreements with rate regulators on projected needs and costs have been made, any of the various organizational arrangements, including those currently existing, has the potential to provide the necessary economic incentives. Although the risks associated with the design, construction and operation of a nuclear project need to be taken into serious consideration, the Study Group concluded that the most severe risks continue to be those associated with political and regulatory institutions.

The Study Group found that some of the proposed arrangements, particularly risk sharing and generating companies, have the highest potential to reduce the political risks. These arrangements however, involve both an industry consensus-building process and/or an elaborate implementation process.

Appendix D provides more detail on the definition of the arrangements studied as well as a discussion of potential advantages and disadvantages.

To further this discussion, the Study Group plans an interactive workshop for the spring of 1987. This workshop would bring together industry leaders to discuss institutional reforms that have the potential to reduce financial risk resulting from political processes. Participants will include utility CEOs, and financial and regulatory experts. Using case studies, the workshop will provide impetus towards the development of new ways of looking at problems, new solutions, and new methods of implementing them.