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LARGE-SCALE FUEL CYCLE CENTERS

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The Energy Reorganization Act of 1974, which created the Nuclear Regulatory Commission, authorized and directed the new Commission to make a Nuclear Energy Center Site Survey (NECSS). Nuclear energy centers in the United States could include nuclear power plants or other appropriate elements of the nuclear fuel cycle or both.

The NECSS was to include a national survey, considering each electric reliability region (or other regional breakdown) of the U.S. to locate potential sites for the centers. The Commission was directed to evaluate the survey and to report any conclusions and recommendations that it might have concerning the feasibility and practicality of nuclear energy centers.

On January 19, 1976, exactly one year after the NRC officially came into being, it delivered an important study to the Congress, Nuclear Energy Center Site Survey - 1975 (NECSS-75)*, responding to the Congressional mandate. Contained in this document is a comprehensive analysis of the feasibility and practicality of three basic types of nuclear energy centers.**

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* Report number NUREG-0001

** The Commission's study was national in scope and thus, for example, considered safeguards questions from the domestic U.S. point of view. Since the time of the study, the U.S. has announced a program to evaluate reprocessing and plutonium recycle in an international context.

- Power Plant Centers (Power NECs) involving ten to forty units of 1200-MWe each. (The 1200-MWe unit capacity was selected in the light of current U.S. practice and established plans.)

- Fuel Cycle Centers (Fuel Cycle NECs) involving fuel reprocessing plants, mixed oxide fuel fabrication facilities, and high level and transuranic radioactive waste management facilities -- with capacities corresponding to the fuel throughput and discharge of about 40 to 240 1200-MWe reactors. More specifically, two models for centers were considered:

  - Collocated Facilities - the location of one reprocessing facility with one mixed oxide fuel fabrication facility with matching production capability on the same site -- to accommodate about 40 1200-MWe LWRs.

  - Integrated Fuel Cycle Facilities (IFCFs) - the location on one site of several fuel reprocessing plants and several matching mixed oxide fuel fabrication facilities, together with waste management facilities to form major regional complexes. The fuel from up to 240 1200-MWe reactors would be handled at an IFCF.

- Combined Centers, containing both power plants and fuel cycle facilities in representative possible combinations.

In the context of the NECSS, the term feasibility is used synonymously with technical feasibility. A judgment that NECs are feasible would reflect findings that (a) no insoluble technical problems prevent implementation of NECs, (b) sufficient technical knowledge exists to limit uncertainties to acceptable ranges, and (c) no technical problems are involved whose solution, though technically possible, would entail clearly excessive costs.

The term practicality is used in this report in the sense of a judgment that (a) no manmade constraints would preclude implementation and (b) implementation would not lead to unacceptable impact on the public interest. While feasibility evaluation is primarily a technical study, the practical issues of implementation are people-oriented: they involve the various interests, perceptions, and values of people and the characteristics and applications of institutional instruments.

COMPOSITION OF FUEL CYCLE FACILITY CENTERS

Of primary interest for NECSS purposes, and for our purposes in this paper, are the fuel cycle facilities that would be related to a program of recycling plutonium recovered from spent fuel into new reactor fuel. The Nuclear Regulatory Commission is presently considering whether large-scale recycle of plutonium may be permitted considering health, environmental, safety, and domestic safeguards issues. The NECSS makes no judgment of the outcome of this consideration; however, it makes the assumption of plutonium recycle, since the safeguarding of plutonium has been a primary motivation for consideration of the center concept for fuel cycle facilities. The facilities in question would include reprocessing plants for spent fuel, fabrication plants for fuel which includes recovered plutonium for recycling into reactors, and facilities for radioactive waste disposal. For enrichment plants that produce the low enriched uranium fuel for the light water reactors of today's U.S. technology, there appear to be no clear motives for collocation with other fuel cycle facilities. Accordingly, no special consideration was given in the NECSS to location of low enrichment plants at NECs.

In later years, volume and other factors warranting, fuel cycle or combined centers could also contain topping enrichment plants -- for taking partly enriched uranium to the higher enrichment needed for high-temperature gas-cooled reactors, and associated HTGR fuel fabrication facilities -- and breeder fuel processing and fabrication plants.

THE INDUSTRIAL CONTEXT

Forecasts point to substantial further growth over the years ahead for both the electric power industry and the proportionate role of nuclear power. While such forecasts are necessarily surrounded by ranges of uncertainty, the projections clearly suggest that sites will be required for a large number of nuclear generating units. Furthermore, accurate forecasting was not found to be important to the analysis of the nuclear energy center concept for either reactors or fuel cycle facilities.

For the NECSS, a number of forecasts for the growth of the electric power industry and its nuclear component -- made by organizations in and outside of government -- were analyzed. At the time, a representative forecast was considered to be Case A of WASH-1139(74) issued in 1974. In this forecast, the United States' 1975 electric generating capacity of approximately 500,000 megawatts (MWe) was expected to triple in the next quarter century. The nuclear portion of that capacity would rise from its 1975 value of 7% to a little over half by the year 2000. Thus, the forecast projects a year 2000 nuclear generating capacity that exceeds today's total generating capacity. The WASH-1139 Case A forecast would mean approximately 600 new nuclear generating units in the next 25 years, assuming an average unit capacity of 1200-MWe (approximately equal to the highest capacity units in existence or being built today).

Today, forecasts by the same organizations are a little lower for total electric power production but the nuclear component has been reduced considerably, and the equivalent of Case A (WASH-1139(74)) is now down to about 50,000-MWe. As just noted, however, the general NECSS conclusion would not be affected by this change and a considerable number of sites would still be required for nuclear generating units. Following the projections of WASH-1139(74) Case A, spent fuel from the reactors can be handled by a maximum of 10 fuel reprocessing plants and 10 matching mixed oxide fuel fabrication plants of present commercial design and capacity.* Here again, based on the later nuclear power projections

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*Reprocessing plant capacity approximately 1500 MT/year; Mixed Oxide fabrication plant matching capacity approximately 300 MT/year.

and probably larger sized reprocessing and fabrication commercial plants, the number of such plants required might be closer to one-half the above.

FINDINGS AND CONCLUSIONS REGARDING THE FEASIBILITY AND PRACTICALITY OF FUEL CYCLE NECs

In the time allowed, it is only possible to give highlights of the findings and conclusions of an extensive undertaking. Indeed, it is necessary to read the detailed analysis to place the following remarks in the proper context.

The NECSS has led to the conclusion that it can be feasible and practical to locate nuclear fuel cycle facilities on nuclear energy center sites. Although the need for fuel cycle NECs is not compelling, such centers might offer public benefits.

Domestic Safeguards - With respect to fuel cycle NECs, the study concluded that collocation of U.S. spent fuel reprocessing and mixed oxide fuel fabrication facilities might be advantageous from the safeguards standpoint, by reducing the number of shipments of plutonium compounds between the fuel reprocessing and fuel fabrication plants. Nevertheless, NRC safeguards studies have indicated that nuclear materials can be effectively protected in the U.S. against theft or sabotage without eliminating the shipment of these plutonium compounds.

The safeguards advantages of collocation options should be viewed in the following perspective: Any step in the fuel cycle that can be eliminated is one less step to safeguard; any step which can be simplified or reduced in magnitude is likely to be easier and/or less costly to safeguard.

Collocation, by eliminating some transportation steps and shortening others, can thus have a beneficial effect. NECSS-75 concludes, however, that flexibility in use of escort forces, combined with other features of in-transport protection (vehicle design, in-transit communications and response systems, planning and control of movement, etc.) allows a transportation safeguards system to achieve the level of effectiveness of a fixed site system. Thus, dispersed facility siting is not excluded on the grounds of effectiveness, although collocation, by reducing transportation, appears to have safeguards advantages.

The influence of safeguards costs on a nuclear siting decision appears to be relatively inconsequential. Fixed site safeguards (for such measures as admittance systems, detection systems, barriers, alarms, active delay devices, access control procedures, employee screening, and material control and accounting) remain approximately the same for the three siting options, i.e., dispersed, collocation, and IFCFs. Furthermore, capital and operating costs for safeguards at the fixed site amount to only a few percent of the total capital and operating costs for the fuel cycle facilities. The analysis of transportation safeguards costs for the three siting modes does little to change the overall conclusion -- mainly because under the most unfavorable cost option, i.e., dispersed siting, planned <u>total</u> industry costs are considerably lower than fixed site safeguards operating costs. Furthermore, fuel cycle NECs show only about 10% lower transportation safeguards costs because most of the costs are associated with the transport of fresh fuel to reactors.

Costs -- Estimates of reprocessing plant and fuel fabrication plant capital and operating costs have increased sharply in the past few years. While only about 5 years ago, reprocessing costs in the range of $30-40/kg of uranium appeared reasonable, most estimates are now on the order of $150-200/kg. There are several reasons for this increase, a primary one being the recent escalation in construction costs -- about 18% in 1974 alone. Other reasons include recognition of the need for additional facilities at the reprocessing plant, e.g., improved effluent control, inclusion of facilities to convert plutonium nitrate to plutonium oxide and new estimates on waste management requirements and costs.

Some construction and operating economies should be obtainable, especially with the larger IFCFs. Advantages could accrue from a stabilized construction force; these advantages are limited by non-uniform craft requirements during the construction period. Common ownership of collocated reprocessing and mixed oxide fuel fabrication plants could enhance economies. Fuel cycle NECs, particularly IFCFs, could offer significant opportunities for improved waste treatment and management facilities. IFCFs would facilitate the volume-reduction processing of wastes before permanent disposal. Further, if IFCFs could be located at or near storage sites for high level and transuranic wastes, then shipment of most such wastes could be virtually eliminated. NECSS-75 does not treat these aspects in detail.

Siting -- Siting of fuel cycle facilities presents a considerably smaller problem then the siting of reactors. By 1990, five sites at most will be required for fuel reprocessing and five for production scale mixed oxide fuel fabrication plants, if there is regulatory approval of wide-scale use of mixed oxide fuel and implementation by the industry; as already noted, the numbers could approximately double by the year 2000, but it is more likely that fewer plants and sites would be needed.

The collocation of a reprocessing plant and a fabrication plant of matched capacity would halve the number of sites required. Not only is the number of sites required a small percentage of the reactor sites needed, but also fuel cycle facilities do not have significant water requirements or heat dissipation or transmission problems. Even integrated fuel cycle facilities (IFCFs), which may have as many as 12 reprocessing and fabrication plants on one site (according to the model used in the study), present no real technical difficulties in siting from the standpoint of meeting safety and radioactive effluent management requirements; in fact, radiological impact (already very low with dispersed siting) could even be slightly reduced from the total impact standpoint at the dispersed sites.

There would be a reduction in the number of sites that might have to be dedicated to permanent care because of residual materials from reprocessing plants. Two or three IFCFs could accommodate the projected domestic fuel cycle needs of the year 2000.

Environmental -- There are no significant differences between the environmental effects of NECs and dispersed sites.

Social Impacts -- The peak population increase associated with an IFCF is estimated to range from 10,000 to 35,000 (including the "multiplier" for families of workers and for new support families), depending on location. Also, population stability in the area can be expected because long-term employment of operating staffs matches the peak construction level. Since no more than about 2 or 3 IFCF sites would be required in the U.S. by the year 2000, the overall social impact would be small.

Antitrust -- Separate ownership at a collocated site could result in a highly dependent supply and demand relationship between the two companies involved, in the reprocessing and the fabrication steps, respectively. For an IFCF, there could be competition onsite -- and being on the same site with one's competitors eliminates any geographical marketing advantages. It was concluded that these potential antitrust problems could be addressed by an approach emphasizing planning with the antitrust considerations in mind -- and that antitrust issues would not be critical constraints to the development of fuel cycle NECs.

Ownership and Management -- Unlike nuclear electric power generation, spent fuel reprocessing in conjunction with mixed oxide fuel fabrication represents a potential future, rather than existing industry. Today only one commercial reprocessing plant in the U.S. is slated for commercial operation and it is not yet completed. There are no large-scale commercial mixed oxide facilities. Industry plans with respect to numbers of units and common or separate ownership; management, and siting of reprocessing and mixed oxide plants depend on the outcome of on-going proceedings concerning the use of mixed oxide. How such a prospective industry would view the merits and drawbacks of investing in facilities at NECs is recognized as a significant practical question. It was believed that the problem of multiple ownership and management of several fuel cycle facilities on an NEC could not be effectively addressed at this time. Obviously, there are potential problems that could be significant (e.g., protection of proprietary information; possible preferential position depending on whether the facility is first, intermediate, or last to be built on a site; and industry-Federal interfaces). It is also true that there are a number of potential ownership arrangements (private, public, and combinations) that could work.

COMBINED CENTERS

Nothing was found that would preclude combining power and fuel cycle NECs; however, important issues do exist that could affect decisions to combine these centers, particularly if the fuel cycle facilities were sized to match the needs of the onsite reactors.

At a combined NEC, the study combines reactors and supporting fuel cycle facilities on one site. The 1500 metric ton per year reprocessing plant and matching mixed oxide fuel fabrication plant can serve the needs of 40 reactors, equivalent to the largest power NEC studied. Thus, the fuel cycle facilities added in this case would be the equivalent of the collocated fuel cycle NEC. There are a number of combined NEC options possible, varying from the virtually self-contained 40 reactor complex described above to smaller numbers of reactors with matched small capacity reprocessing and MOX plant combinations, as well as non-capacity-matched combinations.

Since dose from iodine emissions from both reactors and fuel reprocessing plants may be limiting commitments in terms of design objectives, the dose from iodine releases at a combined site may constitute a limiting consideration in evaluating the radiological impact of combined centers. However, larger exclusion areas, increased stack height for reprocessing plants, and/or control over dairying would mitigate the problem.

Reduction on spent fuel and fabricated fuel shipments would reduce transportation safeguards requirements and also reduce safety risk in transportation (although this risk is extremely low).

Once fully developed, the combined NEC would virtually eliminate the need for both plutonium and mixed oxide fuel shipments offsite; where the fuel cycle facilities are matched to the reactors onsite, spent fuel shipments would also essentially be eliminated.

Offsite fuel and/or plutonium dioxide shipments would be required under any of these scenarios, if there were a prolonged outage (one year or longer) at one of the fuel cycle plants. Otherwise, reactor shutdowns and/or power curtailments would result. Also, during the time the reactors are being built, the fuel cycle plants would have to rely on offsite reactors for operation at optimum capacity.

Substantial fuel cycle cost penalties -- ranging from 1% to 4% of the total cost of electric power -- are estimated for combined centers at which fuel cycle plants are constrained to sizes smaller than those presently planned for dispersed fuel cycle plants. These smaller plants are significantly displaced from the optimum in terms of capital and operating cost effectiveness. Not surprisingly, therefore, the upper range of cost penalties in our study is associated with combined centers containing ten 1200-MWe reactors.

The concept of special plutonium burning reactors, to be collocated with the fuel cycle facilities, offers a potentially attractive approach to combined center implementation, subject to satisfactory design development for such reactors. Such an approach could eliminate or greatly reduce offsite shipment of recovered plutonium, and do it with much less power generating capacity onsite. Plutonium burning reactors would be fueled with mixed oxides of plutonium and uranium like other light water reactors operating on plutonium recycle; however, the plutonium content of the fuel would be increased to a much higher level, thus displacing enriched uranium. While it is known in principle that light water reactors can, in this way, utilize approximately three times as much plutonium as they generate, optimized designs remain to be developed and demonstrated. A demonstration program might involve a decade or two. NECSS-75 did not include a cost-benefit analysis of such a program.

There is another potential advantage -- an economic one -- for the combined center that utilizes the plutonium burner concept. Generally speaking, with fuel cycle facilities handling plutonium, the size and economics are primarily controlled by the amount of plutonium involved. Since 10 plutonium burner reactors would be fueled with about the same amount of plutonium as 30 LWR's on "normal" recycle, fuel cycle plants required to serve these reactors would be near optimum commercial size.

The combined NEC with, in effect, mandated customer supplier relationships through shipment restrictions could further complicate the antitrust issue. Careful regulation would be required.

Conceptually, combined centers can be extended to accommodate LMFBRs (liquid metal fast breeder reactors). In fact, the recovered plutonium from the LWR reprocessing plant would be used to fabricate LMFBR fuel. Furthermore, the onsite mixed oxide fuel fabrication plant can be designed to be capable of manufacturing both LWR and LMFBR fuel. In the future, spent fuel from LMFBRs could be reprocessed onsite, or in a new LMFBR fuel reprocessing plant on the combined site.