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A Siting Policy for an Acceptable Nuclear Future

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This article is an outgrowth of studies (1) aimed at devising an acceptable nuclear energy system for the United States. The nuclear option is in jeopardy largely because it no longer commands a clear public consensus. Our objective is

Summary. A nuclear siting policy leading to a few, large concentrated sites, it is argued, is preferable in the long run to the present policy which could lead to many dispersed sites. Such a policy could be implemented incrementally if requirements for new nuclear generating capacity were met by adding reactors to the existing 100-odd sites. Such a concentrated nuclear siting policy would, to some extent, isolate nuclear activities while augmenting the strengths of the institutions responsible for managing them. Additionally, it would confer an element of permanence on the sites and thereby open new options for managing low level wastes and reactor decommissioning. These actions may improve the public acceptability of nuclear energy in the United States as well as lead to a more rational contained nuclear system in the long run.

to help rebuild a consensus for nuclear energy. Our underlying assumption, which we support with reasoned argument rather than systematic evidence, is that the nuclear system will be more acceptable if it is confined to fewer sites rather than dispersed to more sites. In this article we show that a practical path to a nuclear system consisting of relatively few large sites is to place new reactors largely on existing sites.

That nuclear energy is in trouble hardly needs belaboring. Although there is still a backlog of 126 domestic light water reactors to be completed by the early 1990's, in 1977 only four reactors were ordered by U.S. utilities; in 1978 two were ordered. Licensing and construction of a new reactor can now require 12 years or longer and cost the utility hundreds of millions of dollars. In California there is a de facto moratorium on nuclear energy following the recent opinion of the State Energy Commission that the Sundesert plant cannot proceed unless a satisfactory method for permanent waste disposal has been demonstrated. Nuclear moratoriums have been voted in Montana and Hawaii; and in other states as well as Europe (for example, Austria) the future of nuclear energy is uncertain.

In the long run, we cannot rule out the possibility of a nuclear fission system in the United States consisting of about 1000 large (~1000 megawatt-electric) reactors. This is larger than many current projections of nuclear energy. On the other hand, a system of this magnitude by some time in the 21st century is plausible if (i) the concentration of CO_2 in the atmosphere really is reaching dangerous levels, (ii) solar energy proves to be much more expensive than its proponents hope, (iii) nuclear fusion continues to evade us, or (iv) electricity continues to encroach on other forms of energy. None of these contingencies seems remote to us; we therefore believe it is prudent to examine the implication of an asymptotic nuclear system consisting of 1000 large reactors.

Is a 1000-reactor system more appropriately sited on, say, 500 separate sites, or 100 sites? There are many answers to a question of this sort. Some utility executives see no advantage in confining the nuclear enterprise to a few sites rather than allowing it to spread to many sites: 500 sites, with an average of two 1000-MWe reactors each, would pose no greater problems, and indeed might pose fewer problems, such as heat dissipation and transmission, than would a much smaller number of sites. And from the point of view of some utilities, smaller local sites are generally preferred to larger, more remote ones (2).

The perspective of the federal government may be quite different. The government must look at the system as a whole. The larger the nation's nuclear system, the larger the probability of failure of any kind—reactor malfunction, transport accident, sabotage. Since nuclear matters have acquired such sensitivity, a failure anywhere in the system is likely to affect confidence in the entire system. Thus, measures deemed sufficient to reduce probabilities of failure or consequences of failure by an individual utility operating, say, two or three reactors may not be sufficient as viewed from the perspective of the federal government concerned, as it must be, with the integrity of and the public's confidence in the entire system.

The government must also consider the very long term: presumably it will survive any reorganization of a particular utility or group of utilities. The permanence of reactor sites and the disposition of radioactive wastes—matters that involve very long-term commitments—are more appropriately the concern of the government than the concern of a particular utility.

The arguments favoring a confined siting policy leading to large, permanent

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nuclear sites include minimizing land vulnerable to contamination, simplifying security and site inspection, reducing handling and transport of radioactive materials, and easing the burden of reactor decommissioning. But the primary argument favoring concentrated siting is that such a policy is likely to bring in its wake certain institutional and behavioral changes that we believe are necessary for a large nuclear system and desirable even if the system does not grow very much. These likely institutional changes are suggested by experience at the large nuclear sites, particularly Hanford and Savannah River. Hanford has been in existence for 35 years, Savannah River for about 30. These large, long-lived centers have given rise to operating corps of unexcelled competence. Such competence, including organizational strength and memory, capacity to respond to emergencies, and better construction and quality assurance practices, is an important ingredient of a successful long-term nuclear energy system. We believe that the experience gained from the Hanford and Savannah River sites is applicable to large power complexes: such expertise is more likely to exist at a large site than at a small one.

Here we examine the feasibility of a siting policy based on adding reactors to existing sites. We designate this the "existing-site policy," by which we mean that existing sites would be used to their fullest capacity and that new sites, created only by exception, would be so located and of such size to accommodate future needs for the site. This is, of course, a rather extreme position, but we do not claim that in the future there will be no new sites: an existing-site policy would have to be implemented with flexibility. We do believe that confining the bulk of nuclear expansion to existing sites would discourage the creation of new sites with limited potential for future growth and permanence and would encourage the development of large, permanent sites.

Beyond any consideration of the long term, an existing-site policy might help increase the acceptability of nuclear energy in the short run. We base this assertion on two observations. First, about 90 percent of existing sites are already in favorable locations somewhat removed from concentrated populations. Incremental expansion of existing sites minimizes the commitment of additional land and ought therefore to reduce concerns over the environmental impacts of nuclear energy. Second, many of the existing sites have already undergone extensive environmental review and approval. Incremental expansion might require examination only of the impact of the added capacity rather than a full-fledged estimate of the environmental impact of a new site and of alternatives to it.

Other Studies of Nuclear Centers

There have been several studies of nuclear energy centers (*3, 4*). In all of these studies the investigators visualized large energy centers without examining plausible routes for achieving them. By contrast, we are concerned with an expedient strategy for achieving a nuclear system based on energy centers. Since the policy we propose adds reactors to existing sites one by one, it does not necessarily lead to a system based exclusively on energy centers. Some of the sites might eventually develop into the very large centers (20 GWe plus reprocessing) envisioned in the Nuclear Regulatory Commission study (*3*), some might remain relatively small, some might eventually disappear. The incremental approach allows the system to develop rather naturally with minimum stress on existing institutional structures. It may therefore be a more practical approach for achieving a rational long-term siting policy than would one that attempts to legislate nuclear energy centers without regard for the existing energy system.

Objectives

In order to determine the practicality of an existing-site policy we have addressed the question: Can the projected growth in nuclear generating capacity in the United States for the next 20 years be met by expansion of existing sites? If the actual growth is lower than that projected here (an outcome many would consider quite likely), an existing-site policy would be correspondingly easier to carry through.

This question led us to examine four related issues:

1) Which of the existing sites can be expanded and by how much to accommodate the expected growth in nuclear capacity?

2) To what extent can the implied permanence of large sites help resolve such issues as low-level waste management and decommissioning?

3) What legislation and other legal and regulatory changes might be required to allow or to promote the expansion of existing sites?

4) Would an existing-site policy unduly constrain utilities that do not yet have plans for nuclear stations?

The primary question is limited and definite; it is concerned with policy options to be chosen here and now. The siting policy we choose today will strongly shape the ultimate nuclear energy system. We are therefore obliged to contemplate attributes of a long-term nuclear energy system that are likely to be affected by today's siting policy.

Two attributes seem to be important: first, the impact on the structure of the utility industry of a nuclear generating system confined to a few large sites instead of many more smaller ones; and second, the effect of the site size on longevity of the sites and, by inference, on the management of nuclear wastes.

We are unable to give more than opinions on such dimly perceived, long-term issues. As for the structure of the generating entities, it is plausible to expect that coalescence of the generating system into relatively few large sites would further accelerate the present trend toward generation by consortia of distributing utilities.

Longevity, or even permanence, of the sites is a different matter. It has been realized ever since the beginning of nuclear energy that some of the most troublesome questions, such as the disposal of wastes and decommissioning of old reactors, become easier if one concedes a long-lived, stable institutional structure capable of managing these radioactive residues. Thus, if the nuclear sites are perceived as enduring for a very long time, then at least the voluminous low-level wastes and the decommissioned reactors could remain on site for as long as the site endures. Such a strategy would reduce the handling and transfer of radioactivity, and would to this degree tend to enhance the acceptability of nuclear energy.

Would a few large sites be more easily invested with longevity than many small ones? Again, we cannot say, though from our experience at Hanford and Savannah River this seems plausible: future abandonment of these sites seems far less likely than does the abandonment of a small site such as Hallam or Elk River. Thus part of our study is aimed at elucidating the advantages of large, permanent siting, and at estimating the degree to which the proposed policy would create large sites from small ones and confer on them a commitment of permanence.

Method

To assess the feasibility of an existing-site policy, we allocated reactor capacity anticipated by utilities for the period 1988 to 1998 to existing sites (5). These allocations generally match the load growth expected for the period in the vicinity of the site, but were otherwise unconstrained. We then examined how limitations on water, land, transmission corridors, and radiological impact constrain this allocation. Since some electric utilities now have no plans for nuclear energy in the future, we reviewed this potential problem. We also reviewed legislation and regulatory impediments to an existing-site policy and looked for means to encourage such a policy. Finally, we analyzed the extent to which permanence of sites implied in this siting policy could simplify waste management and decommissioning of old reactors.

A 20-Year Plan for Nuclear Siting

In the United States as of December 1978, 70 nuclear reactors are capable of generating 50 GWe on 47 separate sites. According to the latest reports (6) of the nine Regional Reliability Councils that make up the National Electric Reliability Council (see Fig. 1), nuclear capacity is expected to grow to 165 GWe by January 1988 and, although plans are much less firm, from 165 to 343 GWe in the decade 1988 to 1998. The total electric generation capacity is expected to grow from 545 GWe in December 1978 to 1254 GWe by January 1998.

The projected nuclear increment of growth (180 GWe) for 1988 to 1998 could probably be located at nuclear sites already existing in 1988. The resulting plan for expansion is shown in Fig. 2 and Table 1. In brief, 74 sites are expanded; 17 sites remain at their 1988 size; 4 small sites are decommissioned; 5 sites, now under consideration by the utilities, are opened; and 7 new sites, also currently under consideration by the utilities, are judged to be unneeded by 1998 if other sites in the area are expandable. In all, 96 sites would be in operation in 1998. With an existing-site policy, by 1998 the average capacity of each nuclear site would be about 3500 MWe and each nuclear generating utility, on the average, would operate about 5000 MWe of capacity (see Table 2).

Cooling Water Availability

Although not a panacea for all problems associated with power station cooling, closed-cycle (evaporative) cooling does remove a major physical constraint on expansion of sites—availability of large volumes of water needed for once-

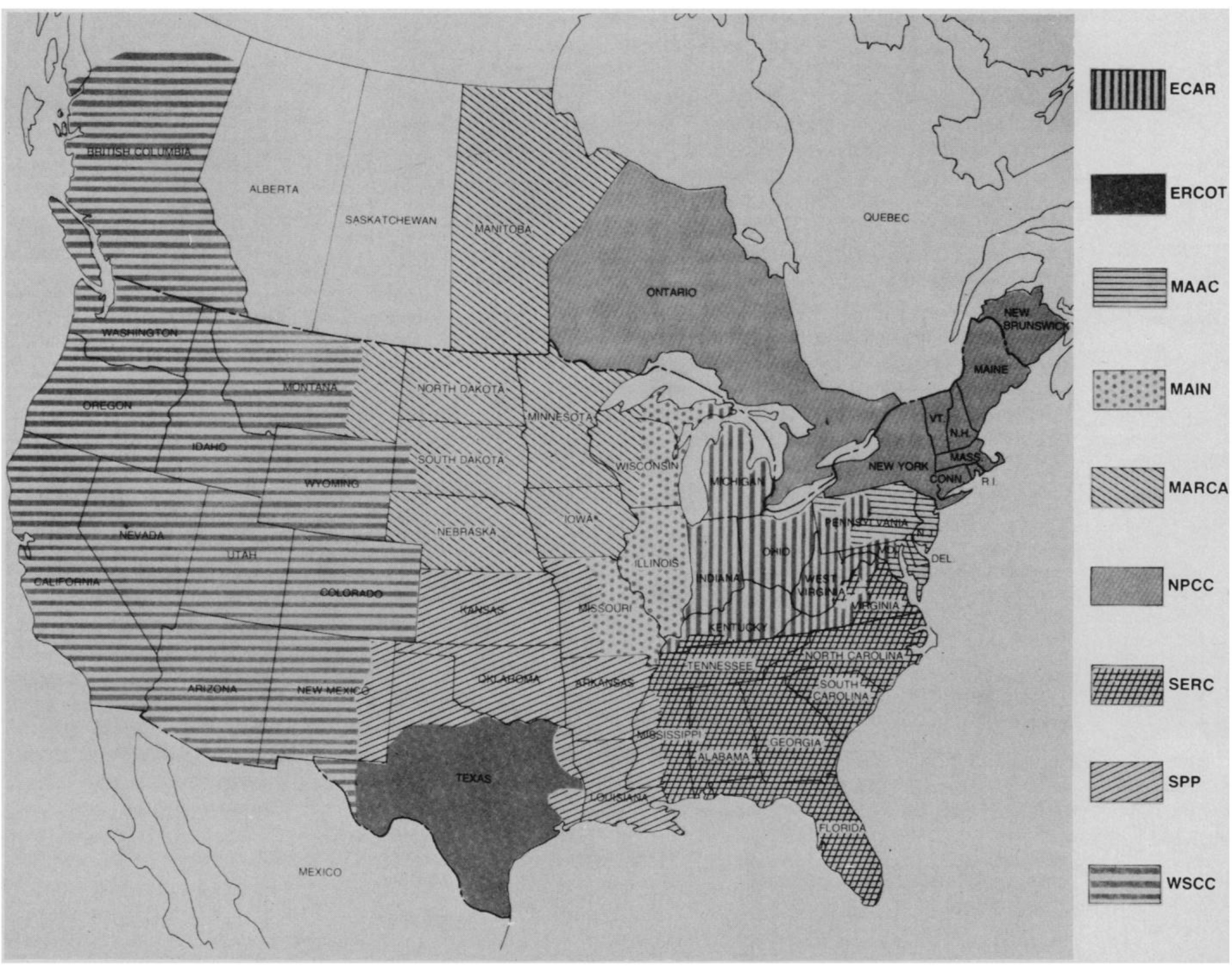

Fig. 1. Service areas of Regional Electric Reliability Councils. Abbreviations: *ECAR*, East Central Area Reliability Coordination Agreement; *ERCOT*, Electric Reliability Council of Texas; *MAAC*, Mid-Atlantic Area Council; *MAIN*, Mid-America Interpool Network; *MARCA*, Mid-Continent Area Reliability Coordination Agreement; *NPCC*, Northeast Power Coordinating Council; *SERC*, Southeastern Electric Reliability Council; *SPP*, Southwest Power Pool; *WSCC*, Western Systems Coordinating Council.

through cooling. With closed-cycle cooling almost all of the waste heat is directly released to the atmosphere rather than to nearby rivers and streams. The evaporative water requirements are modest—25 cubic feet per second on the average for our largest reactors. Closed-cycle cooling systems are now planned for 65 percent of the reactors to be in operation by 1988.

Supplies of cooling water vary greatly among present and planned nuclear sites, being almost unlimited for sites on the seacoasts, estuaries, and Great Lakes and quite limited for the Clinton, North Anna, and Robinson sites, all of which are on streams with average flow rates of less than 300 ft^3/sec. On the basis

Table 1. Allocated site capacity in 1998 based primarily on expansion of sites in operation in 1988. Abbreviations for Regional Reliability Councils are defined in Fig. 1.

Site[a]	Name	Existing capacity as of December 1978 (MWe)	Utility plans for capacity as of January 1988 (MWe)	Capacity with existing-site policy as of January 1998 (MWe)
	ECAR Council			
Indiana				
1	Bailly	0	644	1,900
2	Marble Hill	0	2,260	7,500
Michigan				
1	Big Rock Point	61	65	0[b]
2	Fermi	0	1,093	3,700
3	Palisades	730	740	3,300
4	Cook	2,150	2,150	4,800
5	Midland	0	1,335	1,335
6	Greenwood	0	1,208[c]	5,100
Ohio				
1	Davis-Besse	362	2,718	5,300
2	Perry	0	2,410	5,000
3	Zimmer	0	807	7,300
4	Erie	0	1,260	3,900
Pennsylvania				
3	Shippingport/ Beaver Valley	860	1,784	4,300[d]
Subtotal		4,163	18,474	53,435
	ERCOT			
Texas				
1	Comanche Peak	0	2,300	4,900
3	Allens Creek	0	1,130	2,400
4	South Texas	0	2,500	5,100
Subtotal		0	5,930	12,400
	MAAC			
Maryland				
1	Calvert Cliffs	1,640	1,640	4,200
2	Douglas Point	0	0	0[e]
New Jersey				
1	Oyster Creek/ Forked River	650	1,818	3,100
2	Salem/Hope Creek	1,089	4,338	5,600
4	Atlantic	0	0	0
Pennsylvania				
1	Peach Bottom	2,090	2,090	3,400
2	Limerick	0	2,110	2,110
4	Three Mile Island	1,724	1,724	1,725
5	Susquehanna	0	2,100	2,100
Subtotal		7,193	15,820	22,235
	MAIN			
Illinois				
1	Dresden	1,740	1,740	1,540[f]
2	Zion	2,080	2,080	2,080
3	Quad Cities	1,580[g]	1,580[g]; 1,114[h]	4,000
4	LaSalle County	0	2,156	3,500
5	Byron	0	2,240	4,800
6	Braidwood	0	2,240	2,240
7	Clinton	0	950	1,900[i]
8	Carroll County	0	0	0
	MAIN (continued)			
Missouri				
1	Callaway	0	2,300	7,500
Wisconsin				
2	Point Beach	990	990; 900[j]	4,100[k]
3	Kewaunee	515	515	1,800
6	Haven	0	0	0
Subtotal		6,905	18,805	33,460
	MARCA			
Iowa				
1	Arnold	468	475	1,800
2	Vandalia	0	0	0[l]
Minnesota				
1	Monticello	557	557	1,900
2	Prairie Island	1,046	1,046	4,900
Nebraska				
1	Ft. Calhoun	457	457	3,100
2	Cooper	778	778	3,400
Wisconsin				
1	Genoa	48	48	0[b]
5	Tyrone	0	1,100	3,700
Subtotal		3,354	4,461	18,800
	NPCC			
Connecticut				
1	Connecticut Yankee	575	575	1,900
2	Millstone	1,457	2,641	2,641
Maine				
1	Maine Yankee	781	830	2,100[m]
2	Richmond	0	0	0[l]
Massachusetts				
1	Yankee Rowe	176	176	0[b]
2	Pilgrim	670	1,850	3,100
3	Montague	0	0	2,300[n]
New Hampshire				
1	Seabrook	0	2,300	2,300
New York				
1	Indian Point	1,737	1,906	1,910
2	Nine Mile Point/ Fitzpatrick	1,410	2,521	3,800
3	Shoreham	0	820	3,400
4	Ginna	400	470	1,800
5	Greene County	0	1,200	3,800
6	Jamesport	0	0	3,600[o]
7	Sterling	0	1,150	2,400
Rhode Island				
1	NEPCO (Charlestown)	0	1,150	2,300[p]
Vermont				
1	Vermont Yankee	524	540	1,800
Subtotal		7,730	18,129	39,150

of decisions made to date, we observe that this full range of water availability has been found acceptable from the standpoint of environmental impact and the cost of engineering features needed for water management.

Sites considered for expansion in our analysis (beyond the current plans expressed by the utilities) all have water resources at the site in excess of 3000 ft^3/sec with three exceptions: Comanche Peak and South Texas in Texas and Black Fox in Oklahoma. Of the three, the Comanche Peak site is the most limited (average water flow 1500 ft^3/sec) and may be judged in more detailed analysis to be unsuitable for much expansion considering competing needs for Dallas and Fort Worth. The South Texas site on the Colorado River (average flow 2350 ft^3/sec) is close to the coast and thus seawater could also be used. The Black Fox site on the Verdigris River (average flow 2000 ft^3/sec) near Tulsa is somewhat marginal, but since the much larger Arkansas River flows through Tulsa, it should be possible to manage the total water requirements for the Tulsa area. Ultimately, a new site on the Red River, perhaps near where it enters Arkansas, could centrally serve growth requirements for the region comprising Dallas, Fort Worth, Oklahoma City, Tulsa, and Fort Smith. Three other sites, Palo Verde in Arizona and Sundesert and Rancho Seco in California, have access to the large Colorado and Sacramento rivers, but use of the river water to meet growing needs for power will require interbasin transfer, reallocation of water from lower value uses, or more efficient use of water for irrigation.

Bulk Power Transmission

It appears that the growth expected in power generation from the 1988 to 1998 period could be transmitted from sites in existence in 1988 either by expanding or upgrading present corridors or by creat-

Table 1 (continued).

Site[a]	Name	Existing capacity as of December 1978 (MWe)	Utility plans for capacity as of January 1988 (MWe)	Capacity with existing-site policy as of January 1998 (MWe)
	SERC			
Alabama				
1	Browns Ferry	3,200	3,200	5,800
2	Farley	807	1,684	3,000
3	Barton[q]	0	0	1,300
4	Bellefonte	0	2,426	5,000
Florida				
1	Turkey Point	1,390	1,390	4,000
2	Crystal River	767	767	3,400
3	St. Lucie	795	1,607	4,200
Georgia				
1	Hatch	1,560	1,560	2,900
2	Vogtle	0	2,300	3,600
Mississippi				
2	Yellow Creek	0	2,570	7,800
North Carolina				
1	Brunswick	1,580	1,580	2,900
2	McGuire	0	2,360	3,700
3	Harris	0	1,800	4,400
4	Perkins	0	0	0[r]
South Carolina				
1	Robinson	700	700	700
2	Oconee	2,580	2,580	2,580
3	Summer	0	900	2,200
4	Catawba	0	2,290	3,600
5	Cherokee	0	2,560	2,560
Tennessee				
1	Sequoyah	0	2,296	2,295
2	Watts Bar	0	2,354	6,300
3	Clinch River Breeder	0	0	0[s]
4	Hartsville	0	4,932	7,500
5	Phipps Bend	0	2,466	3,800
Virginia				
1	Surry	1,550	1,550	4,100
2	North Anna	941	3,764	3,765
Subtotal		15,870	49,636	91,500

Site[a]	Name	Existing capacity as of December 1978 (MWe)	Utility plans for capacity as of January 1988 (MWe)	Capacity with existing-site policy as of January 1998 (MWe)
	SPP			
Arkansas				
1	Arkansas	1,750	1,750	4,400
Kansas				
1	Wolf Creek	0	1,150	2,400
Louisiana				
1	Waterford	0	1,165	2,500
2	River Bend	0	1,880	3,200
Mississippi				
1	Grand Gulf	0	2,500	5,100
Oklahoma				
1	Black Fox[t]	0	2,300	4,900
Texas				
2	Blue Hills	0	0	3,200[u]
Subtotal		1,750	10,745	25,700
	WSCC			
Arizona				
1	Palo Verde	0	3,810	6,400[p]
California				
1	Humboldt Bay	63	63	0[b]
2	San Onofre	436	2,636	6,500
3	Diablo Canyon	0	2,270	4,900
4	Mendocino	0	0	3,900
5	Rancho Seco	903	903	3,500
6	Sundesert	0	1,950	4,600
Colorado				
1	Fort St. Vrain	0	330	330
Oregon				
1	Trojan	1,130	1,130	2,400
2	Pebble Springs	0	1,260	2,600
Washington				
1	Hanford	845	3,600	4,900
2	WPPSS (Satsop)	0	2,480	2,480
3	Skagit	0	2,576	3,900
Subtotal		3,377	23,008	46,410
Grand total		50,342	165,008	343,100

[a]Listed alphabetically by Regional Reliability Council and, within each council, alphabetically by state and numbered as shown in Fig. 2. [b]Assumed to be removed from service. [c]1208 MWe of planned capacity that was not designated by the utility to a specific site was assigned to Greenwood. [d]Shippingport assumed to be removed from service. [e]Utility negotiating to cancel units. [f]Dresden-1 is assumed to be removed from service. [g]400 MWe capacity is owned by utilities that serve the MARCA area. [h]In lieu of the Carroll County site; 370 MWe is owned by utilities that serve the MARCA area. [i]Utility plan. [j]In lieu of plans for the Haven site. [k]Includes utility plan for a second 900 MWe unit at the Haven site. [l]Capacity allocated to other nearby sites. [m]In lieu of plans for the Richmond site. [n]Utility plans. [o]Utility is planning for 2300 MWe capacity from Jamesport-1 and -2. [p]Utility plan. [q]Reestablishes site plans canceled by utility. [r]Capacity allocated to other nearby sites in North Carolina. [s]Project status uncertain. [t]500 MWe capacity is owned by utilities that serve the MAIN area. [u]Utility is planning for 1860 MWe capacity from Blue Hills units 1 and 2.

ing a single new corridor. (The transmission voltage need be no higher than is currently in use for the area considered; that is, 500 kilovolts for the South and West, and 345 and 765 kV for the North Central and Northeast.) This compares with perhaps three new corridors per site that would be needed if new sites were to be opened. The extra land that would be required for transmission if existing sites were to be expanded is estimated to range from as low as 0.05 acre per megawatt-electric in the East to as much as 0.45 acre per megawatt-electric in the West. Overall, this incremental land requirement is estimated to be less than 20 percent of that which would otherwise be needed if past and current siting practices are continued.

Questions of system stability are largely circumvented in that existing sites would be expanded incrementally to serve growing requirements in the immediate vicinity of the site. This is to say that if the bulk transmission system envisioned for 1988 is judged to be reliable, then a system for 1998 based on site expansion would be bigger but have similar reliability characteristics.

Table 2. A summary of characteristics for the U.S. nuclear power system with an existing-site policy.

Characteristic	As of December 1978	Utility plans as of 1988	Existing-site policy as of 1998
Total generating capacity (GWe)	50	165	343
Number of reactors	70	172	315
Number of sites with			
Less than 1000 MWe	27	23	2
1000 to 5000 MWe	20	72	78
5000 to 8000 MWe	0	0	16
Total	47	95	96
Number of operating utilities with			
One reactor	24	23	1
Two to three reactors	16	31	28
Four to six reactors	0	8	27
Seven to nine reactors	1	1	7
More than ten reactors	0	2	3
Total	41	67	66

Land

The area of utility-owned land associated with nuclear sites ranges from a few hundred acres (for example, Indian Point with 240 acres, Ginna with 340, and Fort Calhoun with 380) to several thousand acres (for example, Oconee with 29,000 acres and Turkey Point with 24,000). The largest sites include on-site cooling lakes, although many sites are quite large even though they do not include such lakes (for example, Catawba with 8000 acres, Callaway with 6600, and Brunswick with 5025).

The area actually required for locating physical facilities on site may be as low as 15 acres per generating unit for sites with once-through cooling (for example, Fitzpatrick, Kewaunee, Point Beach) but is typically in the 50-acre range when switchyard and cooling tower areas are

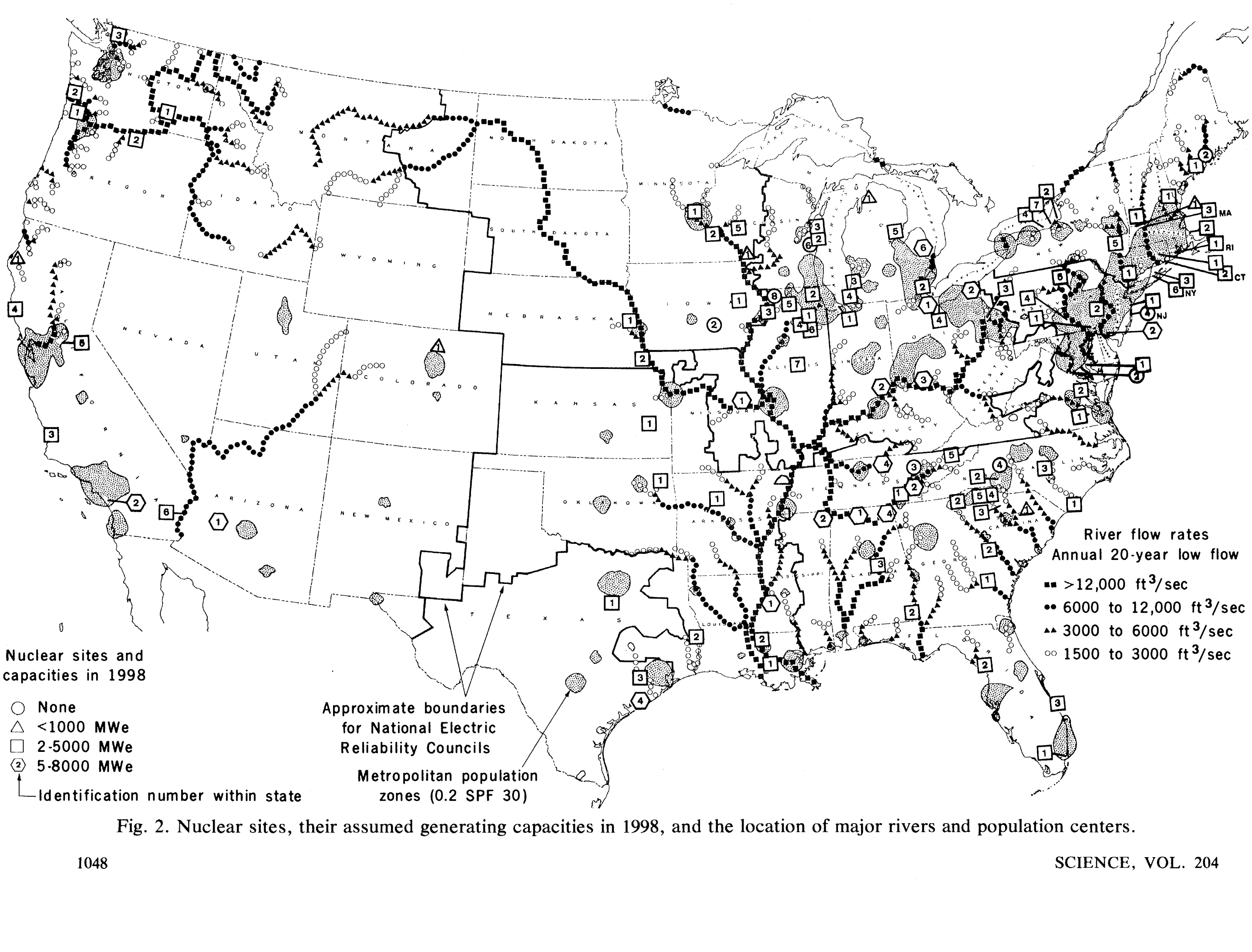

Fig. 2. Nuclear sites, their assumed generating capacities in 1998, and the location of major rivers and population centers.

included. In addition to the area needed for physical facilities, a controlled access area is required to minimize public exposure to operational and accidental releases of radioactivity. This "exclusion" zone is typically 2000 to 3000 feet wide, being less than 1500 feet for nine sites and greater than 3500 feet for 31 sites; this zone can be used for nonnuclear facilities such as cooling towers and switchyards. The area required for a site bounded on all sides by land, and having an exclusion zone width of 2500 feet is about 500 acres; but most sites are bounded on one or more sides by water, and therefore the land area required for exclusion would be somewhat less. The requirement for a controlled access area does not necessarily imply ownership of the land by the utility but rather the capability of controlling the area around its reactors should this be necessary. Thus, industrial operations and other uses of the controlled access area (for example, highways) are possible with the appropriate institutional arrangements.

Of the 74 sites we included in our site expansion plan for the 1988 to 1998 period, we judge that ten may require some additional land for controlled access area. These ten sites are relatively small—less than 1000 acres. Eight of them are in uncongested areas and additional land for incremental expansion ought to be obtainable. Two sites, Bailly and Vermont Yankee, are hemmed in and more land may be difficult to procure. The additional land needed for an existing-site policy is estimated to be much smaller than that which would be required for new sites.

Radiological Impact

In general, an existing-site policy would not be limited by current regulations governing radiological releases. This is mainly because newly built reactors are designed to satisfy release guidelines by a wide margin. Thus, the exposure to the population from expanded sites will be dominated by the older units, with little additional burden being imposed by the new units. For example, the addition of the 1095-MWe Forked River reactor at the Oyster Creek site adds only 10 man-rem to the 490 man-rem expected from the 620-MWe Oyster Creek reactor even when proper consideration is given to the augmented effluent control system for the older unit. Similarly, when Nine Mile Point 2 becomes operational on the site of the Nine Mile Point 1 and Fitzpatrick, it is expected to increase the general population dose only from 15.5 to 15.7 man-rem.

Guidelines issued by the Environmental Protection Agency limit exposure to a maximum of 25 millirem per year per site. Where additional units have been added to existing stations, the total release from these stations has been comfortably in compliance with these guidelines (see Table 3). Thus, it appears that multiunit sites could meet emission standards through the continued use of improved equipment or by control of a small amount of additional land for exclusion areas.

Most Americans, and 78 of the 100 largest cities, are already located within 50 miles (80 kilometers) of a nuclear power plant. In addition, many U.S. cities are typically of the order of 100 miles apart. Thus, establishment of new sites would not reduce the exposure of

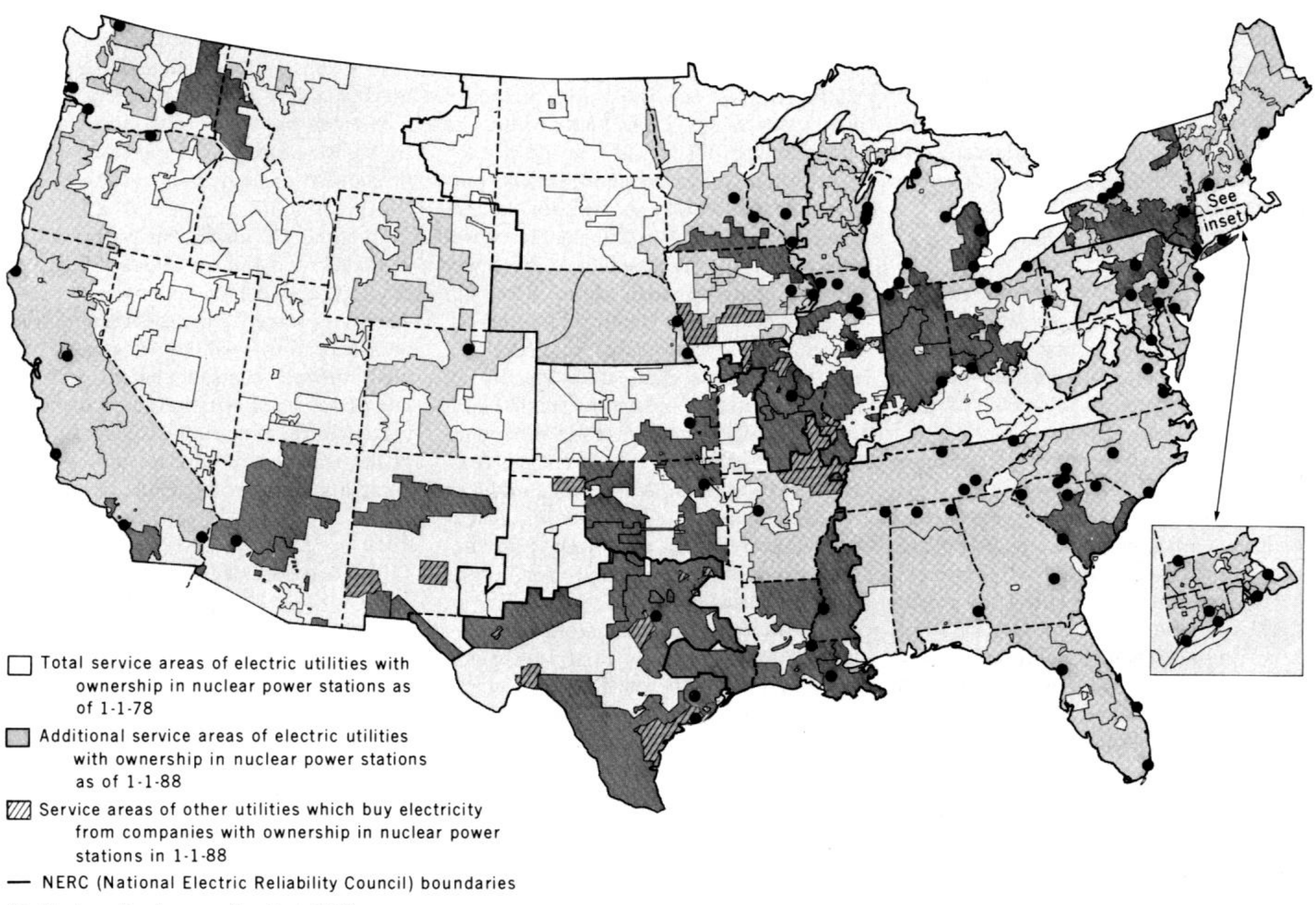

Fig. 3. Service areas of nuclear electric utilities.

Table 3. Radiological assessment at sites with additional reactors.

Site and units	First year of operation	Exclusion radius (feet)	Capacity (MWe)	Liquids and food dose (mrem/year)	Airborne dose (mrem/year)
Millstone					
Unit 1	1970	2000	650		0.5
Improved unit 1 and unit 2	1975		1480	0.002	0.06
Unit 3	1982		1150	0.002	0.02
Oyster Creek					
Original Oyster Creek	1969	2100	620		8.8
Improved Oyster Creek and Forked River	1983		1710	1.1	0.9
Salem					
Salem units 1 and 2	1977	2600	2205	0.05	0.01
Hope Creek units 1 and 2	1984		2130	0.03	0.4
Nine Mile/Fitzpatrick					
Nine Mile unit 1	1969	4000	610		5.0
Improved unit 1			610	0.02	0.07
Fitzpatrick	1975		820	Negligible	3.3
Nine Mile unit 2	1982		1150	Negligible	0.04
Surry					
Units 1 and 2	1972	1650	1710	2.5	0.4
Units 3 and 4			1764	Negligible	0.4
Arkansas					
Unit 1	1974	1800	850	1.8	0.3
Unit 2	1978		950	3.9	0.2
San Onofre					
Unit 1	1968	600	430	0.3	0.01
Units 2 and 3	1973		2280	0.01	0.03

the general population by a large amount. We have not included for expansion the two sites that are closest to large population centers (Zion near Chicago and Indian Point near New York), although these sites seem suitable for measured addition in capacity based on technical criteria alone.

Permanent Sites and Nuclear Wastes

An existing-site policy would create large sites from small and would thus confer on them an element of permanence. This characteristic of permanence leads to continuous management, use, and reuse of the sites and opens new options with respect to waste management, decommissioning of old reactors, and on-site storage of spent fuel.

We find that low-level reactor wastes (that is, contaminated liquids and solids from routine reactor operations) can be handled economically on site and that this practice is technically feasible. Shallow or mound burial techniques could perhaps be utilized for the slightly contaminated wastes that represent 90 percent of the volume of material to be handled, and more permanent, engineered structures, such as a facility with capability for waste volume reduction and retrievable storage, could be used for the 10 percent of the waste volume that contains all but 1 or 2 percent of the radioactive material. If so, the on-site land requirement for, say, 500 cubic meters of low-level waste each year would be about 3 acres for the 40-year life of each reactor, and land is available for this purpose at most of the existing sites. In general, the cost of managing low-level wastes on site is expected to be lower (for comparable methods of handling) than for disposal in regional facilities—if for no other reason than that shipping costs have been eliminated. We do not suggest that all low-level wastes be kept on site in all cases, or that this procedure replace ultimate disposal for some fraction of the wastes. We do conclude that if these wastes are handled for an extended period (that is, decades) on site, the eventual requirement for waste transportation and geologic burial of some fraction becomes more manageable. To this extent an existing-site policy may help moderate the controversy surrounding nuclear waste management.

A similar argument can be made with respect to reactor decommissioning in that if reactor dismantling is delayed for several decades the amount of radioactive material that would ultimately require shipment and burial would be reduced by 90 percent. Similarly, the radiological exposure to personnel charged with the task of reactor dismantling would be lower by 75 percent. Thus some of the uncertainty now beclouding the feasibility of immediate reactor dismantling and site restoration would be removed, and the resulting benefits are likely to outweigh small differences in the estimated relative costs of immediate and delayed reactor dismantling.

Finally, we note that spent fuel could be stored on site for long periods with a minimum commitment to new facilities, procedures, and institutions. On-site storage of spent fuel would eliminate the need to create new sites for interim storage of fuel and the need to transport spent fuel to and from these storage depots until such time that the spent fuel is either reprocessed or permanently interred.

Access of Utilities to Nuclear Sites

It is expected that by 1988, 92 percent of the U.S. population will reside in areas served by nuclear sites. Thus, an existing-site policy would accommodate all but 8 percent of the population. Of these, 3 percent live in the sparsely populated Central West, and 5 percent in areas that are now well endowed with coal, such as Kentucky and West Virginia (see Fig. 3). In these areas, an existing-site policy might ultimately be supplemented by two or three new sites and by some additional long-distance transmission to meet demand in the Central West.

Of some 190 major generating utilities in the United States, about 135 plan to have access to nuclear power by 1988. The trend toward joint ownership of major generating facilities is gaining momentum and suggests that an existing-site policy need not interfere with future participation in nuclear projects by most of the utilities that do not now plan on nuclear generation by 1988.

Legislative Considerations

Legislation and regulation dealing with reactor siting has been based on the current practice of dispersed siting. Thus, for the most part, regulations do not distinguish between existing and new sites.

The Nuclear Siting and Licensing Act of 1978 (7) would encourage an existing-site policy if the act were modified to credit an existing site with having already passed the alternative sites test (if true) instead of requiring de novo consideration of alternative sites and fuels.

Conclusions

The proper ultimate configuration of nuclear sites may well involve a political, not a technical, decision. We have examined the feasibility of confining the nuclear expansion expected for the decade of 1988 to 1998 primarily to sites that will exist in 1988. We conclude that such an existing-site policy is feasible but concede that site-specific studies are necessary to examine the economic trade-offs that such a policy would entail.

We believe an existing-site policy is wise in the long run. It is wise insofar as it ultimately leads to a nuclear system—which may include as many as 1000 reactors—consisting of relatively few large sites rather than many small sites. The benefits of confined siting are not easily measured: they center on the supposition that stronger institutions are likely to be associated with the large sites rather than with small ones, and that the integrity of the nuclear system in final analysis depends on the expertise and organization of those responsible for it. In any event, we believe it prudent even now, before the nuclear system has become very large, to examine ways of arriving at an ultimate system confined to relatively few sites.

An existing-site policy also seems expedient in the short run in that it limits possible environmental impacts to fewer places. Insofar as opposition to nuclear energy is based on its environmental impact, an existing-site policy might make nuclear energy more acceptable, and therefore may help remove some of the obstacles nuclear energy now faces.

An important issue brought to focus in this study is the implication of permanence of the nuclear sites. This is not a new issue in power plant siting: past questions of the long-term integrity and stewardship of dams, which might last hundreds of years, resemble similar questions now being asked about the nuclear expertise. It is our belief that the proposed siting policy is most compatible with such long-term stewardship of nuclear energy. For those who would deny any nuclear future, measures such as these, which we believe improve the acceptability of nuclear energy, will probably be rejected. We would hope that for the many who see benefits in nuclear energy but wish to improve, not reject it, our proposal will be reviewed as a useful step toward an acceptable nuclear future.

References and Notes

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5. Sites for new reactor capacity from now until 1988 have already been selected and development of them is under way.
6. The reports are dated 1 April 1978, and are based on planning information that was current as of 1 January 1978. The projection of nuclear capacity for 1998 given in the 1978 reports is 20 percent lower than the Regional Reliability Councils projected for 1997 in their 1977 reports.
7. An amendment to the Atomic Energy Act of 1954 introduced in but not enacted by the Congress in 1978.

8. This article is based on work performed under contract EY-76-C-05-0033 between the U.S. Department of Energy, Office of Policy and Evaluation, and Oak Ridge Associated Universities.