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Volume 2
Economics of Regionalization: The Electric Power Example

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TREATED WATER DEMAND AND THE ECONOMICS OF REGIONALIZATION

Volume 2. Economics of Regionalization: The Electric Power Example

by

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report presents a data base and methodology for estimating the determinants of residential demands for treated water.

Suggestions are also made regarding methodologies useful for future research into the nature of water system costs by drawing upon the literature on the electric power industry.

Francis T. Mayo, Director
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ABSTRACT

This two-volume report examines the present and future demands and costs for residential water in view of the new requirements for water quality standards under the Safe Drinking Water Act of 1974 (PL 92-523). Volume 1 investigates the determinants of residential water demand (including water price, family income, and appliance ownership) and develops a methodology by which utilties can determine future customer demand. A data base has been developed, and results of the analysis are given. These data can be used to test many hypotheses other than those examined in this study, and they could be a valuable tool for further research into the household demand for water. Methods are discussed sufficiently to provide a point of departure for water utilities that may wish to analyze their own demand.

Volume 2 investigates consolidation in the electric power supply industry as an example of a possible method for offsetting the increased costs of water treatment that will be incurred under the new Federal regulations. The structure of the power industry is examined and the history, advantages, and cost benefits of coordination are evaluated. Several alternatives to the present system are considered, including consolidation of existing systems, encouragement of competitive markets, and public ownership of generation and transmission facilities.

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SECTION 1

INTRODUCTION

The Safe Drinking Water Act of 1974 (Public Law 93-523), which requires the U.S. Environmental Protection Agency (EPA) and State agencies to develop and enforce water quality standards, will have a significant impact on the cost of supplying treated water. One of the consequences of the Act has been an emphasis on the possible benefits of consolidating water suppliers into regional systems to offset some of the increased costs through scale economies and other gains in economic efficiency. This volume investigates consolidation in the electric power supply industry as an example of a possible method for offsetting these new costs of water treatment. The structure of the power industry is examined along with the history, potential advantages, and costs and benefits of coordination. Alternatives to the present power system are also considered.

PRESENT STATE OF THE WATER SUPPLY INDUSTRY

A recent study of treated water supplies in northeastern New Jersey (Greenberg and Hordon, 1976) concluded that a century of evolution in this field had resulted in many separate systems characterized by lack of long-range planning, piecemeal and inequitable arrangements for solving local differences in supply and demand, incomplete projects, and the need for State intervention during emergencies to break institutional logjams. To overcome this situation, Greenberg and Hordon proposed regional management of the water systems. The potential for regional consolidation appears to be great if we consider only the community public water systems (those serving at least 15 permanent users or 25 nonresident users). More than 40,000 such systems are in existence, and more than 90 percent of them have fewer than 10,000 customers (Clark and Stevie, 1978).

THE QUESTION OF MUNICIPAL CONTROL

Historically, treated water has been provided by municipal governments in the United States. Clemens (1950) has suggested the following reasons for this arrangement:

1. Water treatment and supply is a relatively simple operation that can easily be carried out on a small scale.

2. Over the years, few changes have occurred in water treatment technology to make the process more difficult or expensive to provide on a local level.

3. Treated water can be supplied by municipalities as a joint service with fire protection.

4. Treated water supply involves the public health, and as such it is generally viewed as the function of government.

5. Significant scale economies are lacking at the local level.

6. The private sector has failed to enter the market in many cases.

To these arguments can be added the political and equity considerations often used to explain public ownership and regulation of certain economic activities.

Although these arguments may have helped to explain the history of municipal water systems, it is not at all obvious that all of them hold today. Increasing water quality standards and the investments in the sophisticated technology that may be required to meet them certainly will continue to modify the first two considerations. Furthermore, although it may be generally accepted that public health is a proper function of government, it does not necessarily follow that public provision of treated water is the only way to enforce health standards. The regulation of private suppliers (and those who produce their own water) is certainly a viable alternative. (See Cowing and Holtman (1976) for a discussion of this possibility in the context of solid waste collection.)

Factors 5 and 6 may be related in that private investors may not have entered small markets because the system size would not have been economically efficient. But whether or not this was true in the past, the question of optimal system size is relevant to the development of public policies regarding the future of treated water supply systems.

POTENTIAL ADVANTAGES OF REGIONAL CONTROL

The potential advantages of large regional systems appear to result from economies of scale and size that can partially offset rising consumer costs with the declining unit costs that occur as system size increases (Clark and Stevie, 1978). Another benefit of consolidation would be to regulatory agencies, who would have fewer systems to monitor (as of 1975, an estimated 240,000 public water systems existed in the United States) (Clark and Stevie, 1978).

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The electric power industry has attained a high degree of interconnection and significant levels of coordination and/or consolidation on a regional basis; yet the extent of coordination and consolidation has not been as great as had earlier been predicted and advocated on grounds of economic efficiency. The little evidence available to date indicates that few economic benefits have actually been realized from coordination. Moreover, recent studies suggest that some power systems or functions--distribution, for example--are larger than the optimum size.

Because treated water and electric power systems appear to be closely analogous, the evolution of the structure of the latter should provide some guidance for the future development of water systems. This use of the power industry case as a model should include more than just a recognition of the potential benefits of scale economies and operating efficiencies that can be achieved through consolidation and/or close coordination; it should also provide examples of the costs that can offset the benefits in many cases. Perhaps more important, however, the studies cited in this report demonstrate a methodology that is suitable for determining the optimum organizational structure and size of treated water systems. The historical cost data for existing water systems, under development by the EPA, should provide a valuable base for testing hypotheses regarding the extent of scale economies, optimum system size, organizational structure, public/private ownership issues, and regionalization, as has been done in the power industry.

Following Cowing and Smith (1978), particular attention should be given to the following in making such determinations: (1) the level of aggregation (unit, plant, firm, system, etc.), (2) ex ante versus ex post modeling, (3) the behavioral objectives of the organization (i.e., do managers attempt to minimize costs?), and (4) the costs of presumably separable functions such as acquisition, treatment, transmission, and distribution. Selecting the appropriate unit for observation is important because of the possibility that inputs and outputs are not the same across all units at the microeconomic level. Moreover, both technical and behavioral characteristics will be reflected in the data, and these may vary with the level of aggregation. Care must also be taken with behavioral assumptions to avoid possible distortions and biases caused by regulation itself. Thus estimates of cost and other functions derived from particular assumptions about behavior allow more hypothesis testing and more confidence in the results.

Ex ante studies (which refers to estimates of cost behavior based on the potential cost relationships dictated by the technology or production process being used) are useful in the development of policy. These include simulation studies of feasible alternatives (such as the one presented in Greenberg and Hordon (1976))and the estimation of engineering or process production and cost functions as exemplified by the work of Griffin (1972, 1977), Kirchmayer (1955), Marsden et al. (1972), and Smith (1961). Perhaps more important, however, are *ex post* studies using historical data to determine how costs actually behaved with a given technology. Such studies are essential even if the *ex ante* work was predicated upon efficient cost behavior. The *ex post* studies should also attempt to examine alternative organizational forms, system sizes, and other factors that could help determine costs. In addition, the *ex post* approach is useful in comparing the optimum *ex ante* system with what actually transpired, as in the electric power case, in which the extent of actual voluntary coordination among independent systems and realized cost savings appear to have been much less than anticipated, given the early engineering-based estimates.

Only about 42 percent of the community water systems are privately owned, and they supply only 12 percent of the treated water in the United States. These figures suggest that the greatest potential gains from consolidation would be among private systems and/or between publicly owned and private utilities. Although a partial explanation for the existence of many small systems could be the actual lack of scale and other economies usually associated with large systems, their development may also be due to public versus private ownership issues and the use of political boundaries to define service areas. If greater regionalization is warranted on a cost basis, the question of ownership may still have a bearing on the total gains in economic efficiency that can be realized. A regulated, private, regional utility that serves many government units could be a viable alternative to a large public water system.

Finally, alternative ways to capture the potential economies of regionalization may also be viable. These include pooling and/or coordination to the degree that the cost savings warrant, up to and including large systems under common ownership. Moreover, it might be found that a small number of large, integrated systems is not the best solution if the treatment, acquisition, transportation, and distribution functions of treated water systems all exhibit different cost behavior with respect to size. For example, treatment and acquisition may show scale economies, but distribution may not (see Clark and Stevie, 1978, pp. 48-53, on this point). Such results would support the separation of some functions and the encouragement of alternative market structures (see Section 7).

In conclusion, calls for the regionalization of treated water supply systems such as those made by Greenberg and Hordon (1976) should first be answered by studies to determine the optimum size for a system and the extent to which vertical integration, horizontal integration or consolidation, and coordination or pooling appear to be efficient. Recent literature suggests that some electric power supply systems are already too large. Thus it would be prudent to examine the present structure and performance of treated water supply systems and to evaluate the alternatives before a policy is established on the presumption that greater centralization and consolidation is the best course of action. The appendix to this report, which summarizes several of the methodologies that have been used in many of the econometric studies of electric power supply cited in the text, outlines ways in which studies of treated water systems could be conducted to provide policy and rulemaking guides.

SECTION 3

IMPLICATIONS OF THE POWER INDUSTRY EXPERIENCE FOR THE WATER SUPPLY INDUSTRY

INTRODUCTION

The extent to which consolidation of the water supply industry should be carried out depends partly on the determination of optimum size for a treated water system. Few data are available on this point for the water supply industry, but they are available for the electric power industry. The economic structure of the power industry has been studied in great detail over the past 30 years, and arguments for regional coordination can be found in previous studies (U.S. Federal Power Commission, 1964). In addition, many similarities exist between the two industries, so that a study of one may provide valuable insights into the other. Specifically, a survey and evaluation of studies done on the power industry may provide important data on the feasibility of greater consolidation and coordination of water supply systems. Moreover, an analysis of the factors that led to changes in the structure of the power industry over time may help put the regionalization issue into historical perspective.

COMPARISON OF THE WATER AND POWER SUPPLY INDUSTRIES

Most of the characteristics of water supply systems appear to be very similar to those of electric power systems, especially with regard to distribution. The many close analogies between the two systems have been noted by Vennard (1970), and they appear to be close enough so that most of the arguments regarding electric power consolidation, optimum system size, coordination, and form of ownership should be applicable to treated water systems.

In addition to the distribution functions, electric power transmission is the counterpart to water transport, and the power generation function is the counterpart to water acquisition, storage, and treatment. The use of transformers to change voltage serves a function similar to the use of pumps to maintain water pressure during transport and distribution. Both have problems of efficiency such as line loss (heat) for electricity and friction in the case of water pipes. Maintenance of water quality may require filtering and treatment, which is analogous to maintenance of a constant voltage without interruption. Both types of systems are referred to as infrastructure, which implies a network of fixed facilities (lines, pipes, reservoirs, etc.); thus, fixed costs usually loom large in relation to variable, or operating, costs and additional capacity usually involves long lead times, siting problems, and the need for public condemnation and other legal action to obtain rights-of-way. Finally, hourly and seasonal variations in demand often pose significant problems of excess capacity, which emphasizes the need to manage load factors (the ratio of actual usage in a given time period to total capacity of the system measured in kilowatt hours of electricity and gallons (or cubic feet) of water.

There are some basic differences between the two systems; however, these appear to be only a question of degree. A predominance of underground structures distinguishes water systems to some extent, but underground power lines may be a growing trend. Power supply involves some problems that are peculiar to the nature of alternating current generation and transmission. These include the need to maintain synchronization among multiple generating units and a balance between the load, or demand, and the energy being supplied by the generator; moreover, system failures can induce a cascading effect of power surges throughout the system. This necessitates elaborate mechanisms and procedures to quickly remove generators from service and to isolate the failed equipment or even portions of the system. Perhaps the greatest difference is the fact that treated water can be stored and electric power cannot, given present technology.

Despite these possible differences between the system types, the similarities suggest that the potential benefits and costs of regional consolidation in alternative forms may apply to water systems as well as to the electric power industry. Economies of size and/or scale may result in declining unit costs to at least partially offset other forces that may tend to increase costs, such as mandated higher water quality standards.

SECTION 4

EVOLUTION OF THE ELECTRIC POWER INDUSTRY STRUCTURE

The early evolution of the power industry's structure has been due largely to advances in the technology of generation and transmission of electric power, which led to a rapid change from small plants with limited service areas and relative cost inefficiencies to systems that could serve even the largest cities. Thus, many of the original firms were absorbed into the larger systems made possible by technological change. As Kahn (1971) observed, technology has no respect for the ownership patterns that happen to prevail in industry.

In addition to this technological imperative, however, purely financial considerations began to explain the industry's structure by the 1920's. Moreover, broader economic and political considerations appear to have placed some restraints on the industry's responses to technological change.

ORIGINAL FORM OF THE INDUSTRY

The electric power industry began with Thomas Edison's Pearl Street Station in New York City in 1882. The available technology of a reciprocating steam engine and the generation of direct current (DC) limited these first markets to areas measured in city blocks, with transmission lines less than a mile long because of power losses during transmission. The 560 kilowatt plant served 500 customers using more than 10,000 of Edison's incandescent lamps. Earlier central stations at Cornell University (1875) and in San Francisco (1879) provided electricity for arc lamps (Phillips, 1969).

In addition to the small firm size dictated by the technology, the little regulation that existed took the form of city franchises that were either granted to more than one firm as a deliberate competitive policy or simply served as a general franchise to all applicants (Hellman, 1972).

Thus by 1905, Chicago had 29 firms in operation and surrounding cities were served by 18 more utilities. The experience in other cities was similar during this early period, with six firms in Salt Lake City, five in St. Louis and Duluth, and six in New York City (Hellman, 1972). Overall, the existence of as many as 28,000 private and 800 municipal systems serving primarily urban markets by 1902 (see Table 1) strongly suggests that workable competition prevailed in many markets during these early years (Hellman, 1972, and Newberg, 1976).

TABLE 1. NUMBER AND TYPE OF ELECTRIC SYSTEMS FOR SELECTED YEARS FROM 1902 TO 1932*

Year	Number of systems		
	Private	Municipal	Other public
1902	2805	815	------
1912	3659	1562	------
1922	3774	2581	------
1932	1627	1799	3

*Source: Phillips, 1969, pp. 544-45.

EARLY CONSOLIDATIONS

At least two technological innovations began to change the industry structure before the turn of the century: The transformer in 1886, and the steam turbine generator in 1898. The transformer led to the shift away from DC current, which had been pioneered by and favored by the Edison companies, to the generation of alternating current (AC). This was particularly important because it allowed for more economical generation of current at low voltages, which was then stepped up by the transformer to high voltages for transmission to the customer, where it was stepped down to the lower voltages required by the user. High voltage transmission meant lower line losses and larger market areas that could be economically served by a single firm. DC could not be stepped up in the same way (Phillips, 1969). AC is not without its disadvantages, however, including instability under power surges, susceptibility to cascading blackouts when failure occurs in the system, and its requirements for larger conductors, more insulation, and wider rights-of-way for transmission lines. It is now feasible to convert AC to DC after it is stepped up for transmission, and then to revert to AC before stepping down the current. High voltage DC lines appear to be economical for above-ground distances of over 500 miles and underground distances of 40 to 65 miles for up to 600 kilovolts (kV) (Hingorani, 1978). These facts have implications for system reliability and the coordination issues to be discussed in the next section.

Advantages began to accrue to larger firms as smaller firms failed or merged because of their inability to obtain adequate financing for expansion and/or losses caused by destructive competition among rival firms. The term "destructive competition" here refers to industries characterized by high fixed costs, long periods of excess capacity, and inelastic or unresponsive supply. When such conditions are extreme, most if not all firms face the prospect of economic losses for prolonged periods unless they exit or merge.

See Kahn (1971) for further discussion of cases of excessive competition in the face of scale economies.

The following examples suggest the rapidity of the consolidation movement: By 1897, 23 formerly independent firms had disappeared due to mergers with surviving systems in Chicago; Detroit had only one supplier by 1900; and 98 percent of the New York City market was served by one firm in 1907 (Hellman, 1972).

Although increasing economies of scale relative to the size of the market and financing constraints help to explain this early period of horizontal integration (merger of electricity suppliers in the same market) other economic incentives led to broader forms of consolidation, as the following discussion from Clemens (1950) indicates. Many generating firms were acquired by their suppliers of equipment or services. At first, equipment manufacturers may have purchased the stock of electric companies as a means of financing sales of generating equipment, but the advantages of vertical integration soon became obvious when markets could be assured and prices made certain through ownership and control of a firm's customers. By 1905, The General Electric Company had taken the securities of enough generating companies in payment for equipment to warrant formation of the Electric Bond and Share Company to hold the operating company shares. Similar acquisitions were made by companies selling management services, resulting in such consolidated systems as the Standard Gas and Electric Company, General Gas and Electric, and Associated Gas and Electric. As in the case of the equipment companies, this acquisition movement itself became competitive as the service companies sought to prevent the loss of their customers to other systems.

This emerging holding company movement took on its classical form--the creation of corporations to hold the equity (common stock) shares of other firms--when the financial investment motive began to predominate after World War I. Table 2 summarizes the early record of holding company growth. In addition to the potential operating economies from horizontal and vertical

TABLE 2. NEWLY INCORPORATED HOLDING COMPANIES*

Period	Number
Before 1900	5
1900-1909	11
1910-1919	7
1920-1929	46
1930	2

*Source: Clemens, 1950, p. 491.

integration cited earlier, the incentives to form holding companies included the introduction of better and more aggressive management, better access to financial markets, risk reduction through geographic and/or product diversification (e.g., electricity, gas, and fuel oil suppliers), financial leverage, and avoidance of legal restrictions that were specific to certain States or industries.

The major criticism of the holding company in the 1920's emphasized the financial incentive that had the potential for abuse through the pyramiding of ownership by means of multiple layers of so-called paper corporations and widespread speculative acquisition without regard for the physical integration of the system or for the potential instability of the resulting financial structure. Other public policy concerns included the potential for the exercise of monopoly power in local markets and the concentration of broader economic and political power at the national level. The latter problem is suggested by the evidence in Table 3, where it can be seen that only 19 companies accounted for 77 percent of U.S. power sales in 1930. The sheer size of these firms led to fears of undue political influence at the State and national levels.

STATE REGULATION

The first State regulatory agency, the Massachusetts Board of Gas Commissioners, which was created in 1885 and was given jurisdiction over electric companies two years later (Clemens, 1950) was created in response to the power industry's request for the limitation of excessive competition (which provides additional evidence that many markets were competitive during the first two decades of the electric power industry). By 1907, however,

TABLE 3. MARKET SHARES OF ELECTRIC UTILITIES, 1930*

Utility	Percentage of total sales in U.S.
Electric Bond & Share Co.	12.3
Insull Group	12.3
Other large holding company groups (17)	52.4
Largest independent companies (6)	11.1
Other holding companies, independents, and municipal utilities	11.9
	100.0

*Source: Clemens, 1950, p. 499.

consolidation and the resulting increase in local market concentration had prompted State investigations into market structure and the conduct of individual companies. These investigations led to the creation of commissions in New York, Wisconsin, and Georgia in that year to regulate electric power companies.

Within five years, electric utility regulation by commission had spread to 25 other states. In most cases, it was a matter of extending the jurisdiction of previously created railroad commissioners (Clemens, 1950). Thus continuous and direct regulation began to supplant the use of local franchises that had relied on contractual obligations, to the extent that prices and services were regulated at all.

PUBLIC OWNERSHIP

Public ownership, which also began in 1882 at the municipal level, accounted for 22 percent of the suppliers but less than 0.5 percent of the generating capacity and power production by 1902 (Phillips, 1969). As many municipal plants originated in small communities not being served by private firms, they do not appear to have had a significant regulatory influence on electric power markets during that period. By 1907, however, the growing concern over the actual and potential abuse of monopoly power led to consideration of municipal ownership as an alternative to private monopoly, and the numbers of publicly owned systems had more than tripled by 1912 (see Table 1). Hellman (1972) notes that there is little evidence that the economic concepts of efficiency and natural monopoly resulting from extreme scale economies were part of the early discussions of public ownership, although the Massachusetts commission did cite the role of the municipally owned utility as an actual or potential competitor (Hellman, 1972). Some examples did exist of successful duplication of service, in which private firms survived and lower rates resulted (Hellman, 1972).

Table 1 indicates that consolidation activity and the attendant financial and economic forces also had an effect on independent municipal power systems during the 1920's. Other forms of public power were negligible until the late 1930's, and by that time, a resurgence of interest in municipal ownership manifested itself in increases in the number of elections held on the issue. Neither of these developments had the impact on the private sector that the general economic decline and subsequent Federal legislation did during this period, however.

FEDERAL REGULATION

Earlier concern over pyramiding and other abuses of the holding company organizational form was partially realized when more than 50 holding companies, including some of the largest, with share par values of $1.7 billion, failed and another 25 defaulted on interest payments during the first half of the 1930's (Phillips, 1969). Congress responded with the Wheeler-Rayburn Public Utility Act in 1935, which led to a restructuring of the industry and an extension of Federal regulation. Title I of the act gave the newly created Securities and Exchange Commission (SEC) greater jurisdiction over utility holding companies, and Title II placed interstate transmission of electric power under the jurisdiction of the old Federal Power Commission (FPC). This brought not only financial practices but also entry, rates, and service under greater regulatory control, because State commissions had been limited in their ability to deal with interstate transactions in general and holding companies in particular.

Perhaps more important for the purposes of this report, however, this legislation provided for the first Federal attempt to encourage a rational economic structure for the power industry. This goal was implied by the criteria to be used in dismantling the existing holding companies, as stated in Section 11 (b) (1) of the Holding Company Act, in which the SEC was "to limit the operations of [each] holding company system...to a single integrated public utility system, and to such other businesses as are reasonably incidental, or economically necessary or appropriate to the operations of such integrated public utility system." (Other provisions included simplification of corporate structure, stockholder rights and compensation, capital structure, retention of non-electric businesses, and service company regulation.) The emphasis in this Act was on the economic efficiency associated with physical rather than merely financial integration of operating companies horizontally and a recognition of the advantages of vertical integration. The tests to be applied in the case of retention of isolated or nonintegrated systems included: (a) Consideration of the economic viability of an independent operation; (b) they must be located in the same or contiguous States; and (c) consideration of possible impairment of efficient operation and effective regulation. In general, gas systems could not be retained in the same market unless it could be shown that such gas and electric combinations produced substantial economies.

In its case by case examinations, the SEC interpreted integrated systems as being those in which operations were actually coordinated and not merely connected by transmission lines (Clemens, 1950). The potential benefits of coordination will be discussed in the next section.

Of the 2,145 holding companies subject to SEC jurisdiction as defined by the legislation, only 713 remained by 1948 after divestiture proceedings (Clemens, 1950). Abolishment was automatic for all companies more than twice removed from the operating subsidiaries (since many were literally paper corporations), and the rest were subject to SEC scrutiny under the criteria cited above. As Table 4 indicates, the declining number of independent private firms resumed after this period, which suggests that mergers continued to be approved even under the new rules affecting private firms, but the number of municipal systems remained relatively stable into the mid 1960's.

COOPERATIVES AND FEDERAL PROJECTS

Other than the large multi-purpose Federal projects, the major event during this period was the emergence of the cooperative power systems, which were authorized by the 1936 Rural Electrification Act. Although their number stabilized after 1950, cooperatives seem to have had some pro-competitive effects on electric rates and costs.

TABLE 4. NUMBER OF ELECTRIC SUPPLY SYSTEMS, 1937-65*

Year	Private	Municipal	Cooperative†
1937	1407	1877	192
1945	1060	2092	825
1950	821	2077	1054
1955	581	1968	1042
1960	496	2026	1072
1965	472	2114	986

*Source: Federal Power Commission.

†Cooperatives also include some special districts and State projects, except for 1965, when these are included under municipal.

Hellman (1972) and Clemens (1950) have argued that although most cooperatives purchased power for resale from private systems, they posed the threat of potential competition by generating their own power or purchasing from Federal projects. The merits of this argument will be discussed later in more detail.

In a related policy measure, the Public Works Administration (1933) allocated power from Federal projects to systems owned by State and local governments, with about 30 percent of the allotments going to new or existing municipal distribution systems that were in competition with private firms (Hellman, 1972). The Tennessee Valley Authority (1933) and the New York Power Authority (1931) are other examples of government projects intended in part to provide competition as well as cost, price, and service yardsticks for private, regulated monopoly systems (Hellman, 1972).

THE ROLE OF SCALE ECONOMIES IN CONSOLIDATION

The multiple-tier holding company aside, it has generally been accepted that the pattern of horizontal merger during the early period of the industry can be attributed to the technological changes that gave rise to increasing economies of scale relative to the size of the market. Small, independent systems unwilling or unable to expand had merger as an alternative to failure, especially in the more competitive markets. The acquiring system could take greater advantage of these economies by expanding capacity at the same time its market expanded. However, scale economies are not necessary to explain mergers that further enhance monopoly power in local markets. Although the theory is sound, empirical evidence on the nature of power industry costs for the United States was largely unavailable until the late 1930's. The first uniform data on power plant output, inputs, and costs were not published by the Federal Power Commission until 1938, and few econometric studies have examined the pre-World-War-II period. (It remains an unfortunate irony that most uniform data required for research into industry structure and performance have been byproducts of regulation; not only may they have been collected for other purposes, but the regulation itself may distort industry behavior and bias the findings.)

The fact that transmission of power as far as 25 miles was still considered exceptional in 1900 casts doubt on the significance of overall scale economies in explaining the consolidation that took place in the early years; moreover, a study of systems in England for 1928-47 reported that scale economies were exhausted after relatively small plant sizes were attained (Johnston, 1952). Still, studies of U.S. systems using data for years as early as 1938 have found some evidence that significant scale economies existed in the late 1930's and the 1940's (Komiya, 1962; Galatin, 1968; Dhrymes and Kurtz, 1964). Similar results have been reported for the 1950's and early 1960's, although the system size at which scale economies stop increasing was not clearly determined. Some examples are, Iulo (1961), Fuss (1979), Nerlove (1965), Christensen and Green (1976), and Hughes (1971). By the mid 1960's, several related trends were evident. Horizontal merger activity increased, with an average of 40 acquisitions per year of generally small systems (less than 1000-MW capacity) during the decade (Breyer and MacAvoy, 1974). At the same time, a number of voluntary formal and informal intercompany power pools and coordination agreements developed within the framework of a half dozen or so interconnected networks that allowed power interchange among systems. The following section examines this development.

SECTION 5

COORDINATION OF ELECTRIC POWER SUPPLY: HISTORY, ADVANTAGES, AND COST BENEFITS

HISTORY OF COORDINATION

Voluntary interconnection and interchange of electric power had existed long before the FPC involvement. Perhaps the earliest example of what is now termed an interconnected grid was the Great Southern Grid, begun by the Southern Power Company in 1905 to better serve the textile industry in the Southeast. The grid had linked seven independent systems in four States by 1914 and allowed transfers of power between points as much as 1,000 miles apart. By the late 1920's, interconnection was developing in the Northeast, the Midwest, and in California (Electric Power Research Institute, 1979). The creation of the TVA in the early 1930's marked a third major step in the development of regional interconnection as part of a multipurpose project.

Although the potential for coordination existed once interconnection had been accomplished, most of the early use of the grids was for the purpose of evening out load diversity and for emergency access to power supply when such disruptions as decreased hydroelectric generation during droughts occurred. Vennard (1970) traces the beginnings of modern-day pooling to World War II, when expansions in generating capacity were limited by the diversion of resources to the war effort at the same time the defense plants were demanding increasing electric power. For example, 12 companies formed a pool to enable continued service to existing customers plus a new factory complex in Arkansas (Vennard, 1970).

The industry's structure was relatively stable in the 1950's, with most of the emphasis on coordination through pooling of reserve capacity and some staggering of construction; during the next decade, however, the resurgence of the consolidation movement resulted in more common ownership of capacity and transmission lines (Hughes, 1971).

Section 202 (a) of the Federal Power Act of 1935 charged the Federal Power Commission with promoting and encouraging voluntary interconnection and coordination to assure an abundant supply of energy throughout the United States with the greatest possible economy and with regard to the proper use of resources. An outgrowth of that charge was the 1964 National Power Survey, which developed an indicative plan intended to foster greater coordination for meeting projected future power requirements. The United States was divided by this survey into geographical areas at five levels ranging from two zones to 48 power supply areas.

Three interrelated concerns that prompted the survey and subsequent studies and proposals were system reliability, operating economies with existing capacity, and efficient additions to transmission and generating capacity. It was generally accepted that greater coordination of operations and investment planning in conjunction with planning at the national level by the FPC could result in a more reliable and economical bulk power supply generation and transmission system. Furthermore, coordination could serve as an alternative to the consolidation of inefficient smaller systems by merger. The need for greater coordination was indicated by the 1964 survey, which identified 3,190 small systems (less than 25 MW of electricity demanded at their annual peak hour), only 899 of which had any generating capacity (U.S. Federal Power Commission, 1970). By 1968, consolidation had reduced these figures to 2,842 and 800, respectively; moreover, 243 of these small generating systems were isolated from large systems, which were defined as having at least 500 MW of generating capacity (U.S. Federal Power Commission, 1970). In addition to the higher costs of construction per kW and operation per kWh attributed to systems of less than optimum size, the survey found that about 75 percent of the isolated systems had reserve generating capacity in excess of 50 percent of their annual system peak loads (U.S. Federal Power Commission, 1970).

ADVANTAGES OF COORDINATION

The potential advantages of coordination include: (1) the attainment of a system size large enough to justify installation of the optimum size generating plant; (2) the ability to stagger the timing of construction of additions to capacity and the sharing of excess capacity; (3) the sharing of reserve capacity, which otherwise should be at least equal to the capacity of that of the largest plant in an individual system if service is not to be interrupted by failure; (4) the sharing of risks and other costs of financing system investment; (5) circumvention of the problem of a lack of suitable sites for generating plants for environmental or other reasons; and (6) the attainment of load balancing by internalizing demand diversity or differences in seasonal peaks among systems in different regions (e.g., exchange of power between two systems with peak demands in different months--February and August, perhaps).

COMMON TYPES OF COORDINATION CONTRACTS

Although it might appear that the advantages of coordination could best be obtained by interconnected systems under common ownership and management, they are also possible under a variety of voluntary contractual arrangements that existed even before the FPC interest in coordination. The most common types of contracts include emergency power, standby power, supplemental requirements, purchased or all requirements power, exchange of service or economy energy, short-term service, transmission service or wheeling, dump energy, and exchange of capability or unit sales. These contracts are described as follows.

Emergency power is usually provided in the form of short-term purchases on a standby basis with a reciprocal responsibility on the buyer's part and with payment in cash or in kind at the seller's option at prices equal to the marginal or incremental cost plus, (e.g., 10 percent).

Standby power is similar to emergency power, but some plant capacity is set aside for this purpose.

Supplemental requirements are purchases made to supplement a system's own generating capacity on a short- or long-term basis.

Purchased or all requirements power includes sales to a distribution system with no generating capacity on a wholesale or bulk basis with prices that may include capacity, demand, and energy charges.

Exchange of service or economy energy involves delivery of power from the least-cost source; as needed, on a continuous basis in a tight pool or holding company system. The price (which may be a transfer price for regulatory and management accounting purposes only) is usually the seller's marginal cost plus half the difference between that and the buyer's own marginal cost.

Short-term service also involves power transfers within pools, but for periods of weeks at prices that may include demand and energy charges.

Transmission service or wheeling is power that is usually displaced rather than transmitted through a complete system. Charges depend on the nature of the transmission (emergency, etc.) and may include some construction cost allocation and adjustment for line losses.

Dump energy involves sales of surplus hydroelectric power on terms similar to economy sales.

Exchange of capability or unit sales may involve power from jointly owned plants, dedicated shares of capacity, or plants that are part of a staggered construction agreement. Charges usually reflect an allocation of fixed and variable costs.

COST BENEFITS OF COORDINATION

Estimates of potential cost savings have been made for three major categories of coordination: (1) evening out demand or peak-load diversity among systems, (2) pooling of reserve generating capacity, and (3) installing optimum-sized generating plants. Table 5 summarizes estimates by the FPC (Breyer and MacAvoy, 1974) and by Hughes (1971) as to the possible gains from such coordination. The $1.68-billion savings in annual operating costs estimated by the FPC assumes effective coordination of systems within each of 16 regions as designed by the FPC.

TABLE 5. POTENTIAL COST SAVINGS AS A RESULT OF COORDINATION, 1962-80

Category of Coordination	FPC estimates*		Hughes (1971) estimates of Annual Operating costs (in millions)
	Total capacity cost (in billions)	Annual operating costs (in millions)	
Demand diversity	$1.5 to $ 4.0	$ 180 to $ 480	$ 210 to $ 420
Reserve pooling	4.7 to 6.5	564 to 780	600 to 1,200
Efficient plant	3.5	420	930
Total	9.7 to 14	1,164 to 1,680	1,740 to 2,550

*Breyer and MacAvoy, 1974.

Given his own estimates that the elasticity* of total generation cost with respect to unit size was equal to 0.9 during the 1960's, Hughes (1971) recommended a restructuring of the electric power industry into approximately 30 planning and operating units by merger and/or close coordination of public and private systems. Breyer and MacAvoy in 1974 estimated a potential $2-billion annual cost saving by 1980 based on 5-percent reduction in new capacity costs resulting from efficient plant size and economic dispatch and another saving of 6 percent in capacity as a result of reserve pooling. In spite of the agreement of these studies, actual coordination has not developed to the extent projected (see Breyer and MacAvoy, 1974, for a determination of coordination as of 1970-71); thus not all of the cost savings have been realized.

Breyer and MacAvoy (1974), citing several engineering studies in addition to the economic evaluations, concluded that rationalization of bulk electric power supply could be achieved by creating 10 to 15 closely coordinated systems through merger. Of course, this proposal and the similar one by Hughes raise the question of increased monopolization, which might be offset to some extent by other measures (e.g., the dismantling of such vertically integrated operations as generation and transmission). As an alternative, they suggest public ownership of generation and/or transmission lines by a government corporation that would sell to distribution systems. These issues are discussed later in more detail.

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*The elasticity is calculated as the percent of change in cost due to a 1 percent increase in the size of conventional generating plants. Hughes' estimate for the 1950's was 0.8.

SECTION 6

EVALUATION OF EXISTING COORDINATION

A recent study has estimated by econometric techniques the actual cost reductions in the power industry resulting from coordination as of 1970 (Christensen and Greene, 1978). Coordination was defined as formal contractual pooling arrangements, with or without central dispatch, among independent systems or through common ownership by a holding company. Estimates of total generating cost advantages for pool member firms of approximately 4 percent, with an additional 1.3 percent if central dispatch was used, were not statistically significant for a sample of 138 firms. As in the earlier studies, no attempt was made to identify the additional costs of forming a pool, such as new transmission line construction, which biases the estimates of cost savings upward. On the other hand, downward biases may have occurred when possible gains were ignored in reliability and in the environmental benefits of better locations for fewer plants in a larger region.

Although holding company affiliation appeared to result in a 7-percent cost advantage over independent pool members, when regional location and firm size were taken into account, the authors were forced to conclude that formal power pools resulted in no systematic generating cost reductions for their members in 1970. Moreover, this observation implies that any advantages inherent in close coordination could be achieved through informal, arms-length relations among systems (Christensen and Greene, 1978).

In an earlier study by Christensen and Greene (1976), it was found that most firms in 1970 were already operating in the flat or constant long-run average cost (LRAC) range (fewer that 50 percent had unexploited scale economies), and that a 3.2-percent cost reduction would have been obtained if all firms in the sample had operated at minimum LRAC (see Figure 1). If each firm had been of optimum size (output of approximately 32 billion kWh at a cost of 0.473¢/kWh in 1970), 30 percent fewer firms would have existed, a fact that indicates that there would have been potential cost savings through additional mergers among the smaller systems (Christensen and Greene, 1976). Both the 1976 and 1978 Christensen and Greene studies, taken together, suggest that formal voluntary coordination and tight pools have not been a viable substitute for selective mergers. Moreover, these studies help explain why the extent of such coordination has fallen short of the potential cited by the FPC and others. The cost savings apparently were not being realized by the firms in practice. Other possible explanations for the lack of voluntary coordination and/or the apparent lack of realized benefits to existing power pools are worth exploring at this stage. The following discussion draws heavily from Breyer and MacAvoy (1974), Kahn (1971), and Lindsay (1976).

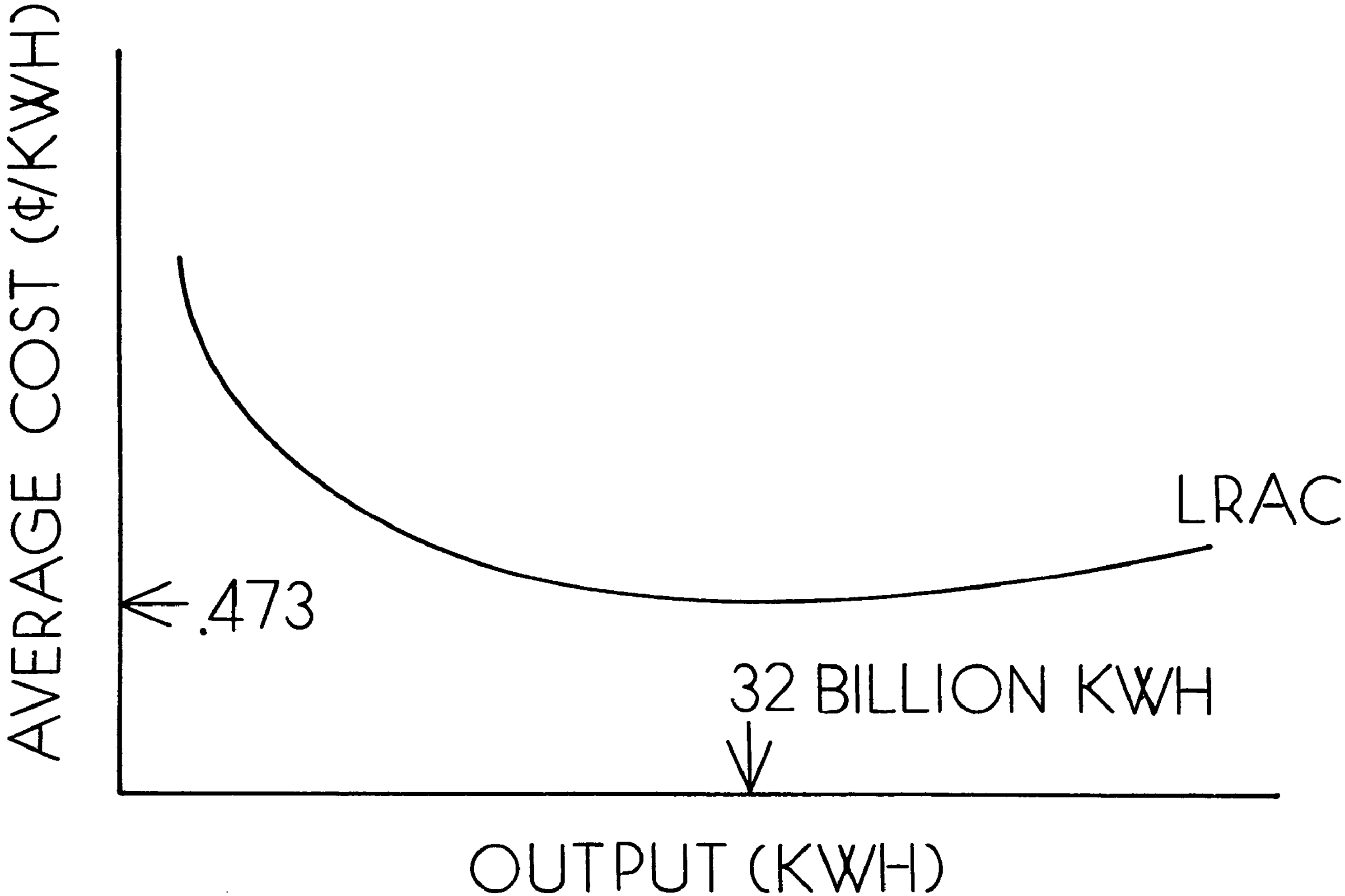

Figure 1. Economies of scale in the electric power industry, 1970.

COORDINATION INCENTIVES AND DETERRENTS

As most electric power is generated by investor-owned (IOU) utilities subject to State and/or Federal regulation, this discussion is primarily concerned with their incentives for and deterrents to coordinating short of actual merger. Yet some of the arguments may also apply to public systems, depending on their objectives as an economic organization. Moreover, the objectives of the IOU and the nature and effects of regulatory constraints are inextricably linked to the coordination issue. Thus, for example, if a regulated franchise monopoly lacks the incentive to minimize costs and/or improve the quality and reliability of its services (which are among the expected benefits of coordination), then the lack of voluntary full coordination is understandable. Or the perceived cost of coordination agreements may exceed the perceived benefits to the individual firm, resulting in less than optimal coordination from the point of view of society. One aspect of the problem of costs and benefits as perceived by the decision maker has to do with private versus social costs and benefits. For example, if the coincident peak load of a coordinated system is less than the sum of the noncoincident peak loads of the member firms, then coordination could benefit each firm (and its customers) as well as society in general by allocating resources more efficiently. On the other hand, if coordination provides a larger geographic area in which to locate generating plants which minimum environmental costs, but the firms and their customers do not recognize or pay such environmental costs, then the incentive for voluntary action is reduced because the private benefits are less than the social benefits.

Another aspect has to do with such added costs that may be associated with coordination as the construction of new transmission lines in order to interconnect systems. Moreover, Breyer and MacAvoy (1974) have noted that the rate of forced outage due to failure has increased with plant size and technological improvement; thus, the gain to individual systems in terms of reduced reserve capacity requirements can be at least partially offset by the need for reserve capacity for the pool if it has both larger and less reliable plants.

Finally, although the State commissions, the FPC, and its successor, the Federal Energy Regulatory Commission (ERC), have long had the authority to require and/or encourage efficient and reliable service, they may lack the incentive to act or they may have conflicting objectives as an institution.

Corporate Behavior

The economic model of the competitive market can be used to explain why an owner-managed firm is forced to attempt to maximize profits and, as a necessary condition, minimize costs in order to survive in the long run. If competition is lacking, if ownership and managerial control are separated, or if a short run decision is involved, it can be argued that other objectives of the firm's management may override efficiency considerations; i.e., it is rational for the hired management to attempt to maximize their own welfare if free to do so. As this would appear to be the environment in which corporate management operates--and if regulation is ineffective--then part of the lack of coordination may be due to the problem of management incentives to achieve cost minimization.

On the other hand, if the owners (stockholders) wish to maximize their profit and if the capital markets are sufficiently competitive--as appears to be the case--then the existence of a monopoly in the market for a firm's product or service is not sufficient to allow this kind of managerial discretion. Moreover, evaluation of managerial performance by the financial press and the potential for corporate mergers and takeovers serve to provide discipline for management to act in the interests of shareholders.

Federal and State Regulation

If the regulatory agencies provide the incentives and/or orders necessary for efficient service, this discussion is irrelevant. But the evidence on the effectiveness of regulation is mixed at best. The classic study by Stigler and Friedland (1970) concluded that State regulation of electric utilities had no effect on prices and returns, and Breyer and MacAvoy (1973, 1974) have concluded that the FPC failed to promote coordination to the extent possible. If regulation is effective to the extent that the allowed rate of return on investment (ROR) is less than the ROR that could have been earned by a profit-maximizing utility, then a distortion often referred to as the A-J effect can arise that gives the firm the incentive to use more capital than would be optimal relative to labor, fuel, and other inputs.* Effective ROR regulation would create an incentive to increase the size of the rate base (value of plant and equipment) to increase the total profit for a given allowed ROR, which will result in a greater total cost than if the input mix were optimal. Thus the utility would have less incentive to participate in pooling and coordination arrangements that reduced rather than increased its rate base (e.g., sharing reserve capacity rather than wholly owning it). The A-J thesis and related distortions resulting from ROR regulation have only recently been subjected to empirical tests, and although there is some evidence to support the argument that this effect is a deterrent to coordination, the evidence is mixed. See, for example, Boyer (1976), Courville (1974), and Spann (1974). The testing of this hypothesis is complicated by the necessity of assuming two other potentially testable hypotheses: That ROR regulation is effective and that utilities attempt to maximize their ROR. Assuming that the theory has no logical inconsistencies, failure to confirm the A-J thesis would cast doubt on one or both of these assumptions. None of these studies has attempted to relate the A-J effect to coordination.

State or Federal regulation could have retarded the coordination movement in several other ways. Power pools that cover several States may encounter State laws and/or regulatory commission rules regarding reliability, reserve capacity, or joint ventures in generating plants as part of capacity-

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*The seminal work on the A-J effect is Averch and Johnson (1962). This effect differs from the older "gold plating" argument (referring to the use of nonproductive plant and equipment or to excessive reliability) and from the inflation of the value of plant and equipment for rate-making purposes. Although these may well be distortions resulting from regulation and have long been the objective of regulatory scrutiny, they appear to be unrelated to the coordination issue.

sharing agreements. Moreover, State commissions may be opposed to having plants that are financed by firms under their jurisdiction provide significant long-term power to customers in other States. Finally, membership in an interstate pool could have brought a utility under the unwanted jurisdiction of the FPC and other Federal agencies, which would inhibit coordination with intrastate systems. But this argument is weakened by the liberal court interpretation of the Commerce Clause (Article I, Section 8) of the U. S. Constitution. Furthermore, since the 1972 FPC versus Florida Power and Light Company case (in which the court ruled that the FPC had jurisdiction over the firm, even though it operated wholly within the State, because it was connected to interstate transmission lines and its electricity was commingled with that of interstate systems), it has been concluded that the FPC has the authority to affect virtually any firm having generation and/or transmission facilities (see Breyer and MacAvoy, 1974).

Competition

Another possible explanation for the less than enthusiastic embracing of full coordination is that there exists present and future competition among utilities that are usually considered to be natural monopolies.

In fact, there are a number of areas in which an electric power utility may face present or potential competition despite its franchise monopoly status: Alternative energy suppliers, self generation by the user, overlapping service areas by IOU, municipal, and cooperative systems, loss of franchise, and competition for new customers, especially by attracting new industries into the system's present service area. For example, a firm may be willing to forego short-run profit increases resulting from cost reductions through coordination in the attempt to gain long-run profits (i.e., by avoiding cooperation that could benefit potential competitors in the sale of power or with systems that could be customers in the future).

POOL FORMATION AND MAINTENANCE

The difficulties in forming a power pool or in maintaining it once it has been organized are similar to those inherent in the voluntary economic associations known as interdependent oligopolies or cartels. They include such issues as the allocation of the costs and benefits of coordination among the members, the resolution of disputes, and control and enforcement of agreements. Just as in the case of legal or illegal cartels, there is an inherent instability problem in pool arrangements among independent systems. Indeed, several closely coordinated pools have broken up because of their inability to resolve such issues by committee management (Hughes, 1971). These problems can become even more acute when central dispatch is considered by a formal power pool. This degree of coordination will not be optimal unless the particular economic circumstances and objectives of each member and the pool as a whole are compatible. Wide divergencies in the proportion of fixed (plant) and variable (chiefly fuel) costs among members can make inter-system pricing and cost sharing arrangements very difficult (Breyer and MacAvoy, 1974).

Size differences and the generation-distribution mix of systems can also have an effect on pool formation. In general, smaller systems would have more to gain in the way of cost reductions than the larger firms, which could also lose more to future competition than would be gained through coordination. This would be particularly true in the case of small distribution systems that generate little or none of their power requirements. Thus voluntary coordination arrangements might be more attractive among large, integrated systems.

Small, distribution-only systems can contribute to the overall gains from coordination in some cases if they have peak demands that are not coincident with the pool and/or if they have large off-peak base loads such as street lighting. Or, they can form a subgroup large enough to enable them to own jointly generating capacity of an economical size, which would allow them to make a greater contribution to the pool. Even in these situations, however, members of a pool would have the incentive to protect themselves by attempting to impose restrictions on each other. These restrictions might concern the markets to be served by members, controls over resale of power to nonmember systems or final users, pricing, and the exclusion of certain systems from membership. Members of a pool who contribute little or nothing would be benefiting from cross-subsidization if their charges did not reflect the costs of servicing them. On the other hand, admitting a system to a pool that was formerly a purchaser from its members could lessen actual or potential competition in wholesale and/or retail markets.

FPC AUTHORITY AND ANTITRUST SCRUTINY OF COORDINATION

For these reasons, the coordination movement in general and certain practices of member systems have been the subject of antitrust scrutiny by the Justice Department and the courts. The following discussion of this subject is drawn from Jones (1976), Lindsay (1976), and Schwartz (1976). In addition to the obvious concern over mergers and voluntary agreements among IOU's to cooperate (which, of course, are agreements not to compete), the courts have dealt with cases questioning FPC authority and jurisdiction under its enabling legislation and the exemption of utilities from antitrust laws because they came under FPC jurisdiction. Smaller, mostly public systems sought rulings that would give them access to pools and relief from alleged anticompetitive practices. In the 1952 Pennsylvania Water and Power Co. versus FPC case, the court ruled that the FPC had jurisdiction over the coordinated interstate system to which the Pennsylvania company belonged, and that antitrust litigation was not material because the FPC had the authority to order or sanction coordination. A year later (U. S. versus Public Utility Commission of California), the court upheld the FPC's authority to regulate wholesales from an IOU to a municipal system. A number of subsequent cases have upheld the FPC's authority to order the granting to small public and private systems of access to power supplies and/or pools. Moreover, certain practices and terms of coordination contracts were found to be anticompetitive. These included requirements that small systems maintain reserve capacity equal to their own largest plant and the charging of wholesale rates not reflective of costs in order to preclude resale of competitive rates. In City of Paris (Kentucky) versus FPC (1968), the court held that the FPC could order an IOU to wheel power, but only if interconnection already existed. In 1971, however, the court ruled that the FPC had the authority to order Florida Power to connect with a municipal distribution system and to set the terms of the contract. The decision in Municipal Electric Association versus SEC (1969) found that an IOU is subject to antitrust regulation if it forms or buys into a company (e.g., a nuclear plant joint venture) and excludes others. The results of more recent litigation (Otter Tail Power Co. versus U. S. (1973); Gulf States versus FPC (1973); and Conway Corporation versus FPC) have supported the contention by the Justice Department and the SEC that a somewhat reluctant Federal commission must consider the broader competitive issues when acting on complaints and issuing orders. Taken together, the list of practices that are questionable now include restrictions on resale of wholesale power, full requirements contract stipulations imposed on distribution systems, wholesale rates so high as to prevent competitive retail rates, market allocation by pool members, refusals to wheel power, and denial of pool membership or equal access to power.

The apparent reluctance of the FPC to exercise fully its authority to promote coordination has been attributed to the nature of institutions that rely on case-by-case hearings, adversary proceedings, and piecemeal approaches to complaints and problems (Kahn, 1971). This factor plus a perceived lack of a mandate to consider the broader public interest has resulted in an emergency or crisis approach to coordination rather than long-range planning in which economic efficiency, reliability, and environmental costs are treated as interrelated issues (Breyer and MacAvoy, 1974).

The 1978 Public Utility Regulatory Policies Act (Sections 202-205 and 209-210) gives the FPC's successor, the ERC, explicit criteria to be used in the consideration of coordination, pooling, and wheeling arrangements, with the emphasis on economic efficiency, reliability, and resource conservation. The public interest and existing competitive relationships are to be considered in issuing orders, and benefit cost studies are called for in evaluating alternative proposals for dealing with these and other issues, including the structure of the power supply industry.

Thus, even though there are recognized potential benefits from consolidation and close coordination, it is also recognized that they are not always realized and that they may not exceed the costs in all cases. Some alternative organizational structures should be discussed before any particular system is suggested for treating water supply.

SECTION 7

ALTERNATIVES TO THE PRESENT SYSTEM

The 1978 Public Utility Regulatory Policies Act requires the Department of Energy to study the cost effectiveness of adding a number of small, decentralized generating units rather than a small number of large generating units of similar megawatt capacity for achieving the desired level of reliability (Sec. 209 (2) (E)). This directive appears to question the earlier arguments for greater coordination and larger plants to achieve reliability. In view of the evidence already examined in this report, however, full voluntary coordination of a few large systems and alternative industry structures should be examined further.

The major alternatives that have been suggested in the literature include: (a) consolidation of existing systems into a relatively few large, closely coordinated and integrated systems, either by merger or by the formation of multisystem pools; (b) encouragement of workably competitive markets where possible, with greater reliance on antitrust regulation; and (c) public construction and ownership of generation and transmission capacity with public or private management.

CONSOLIDATION OF EXISTING SYSTEMS

The first alternative, of course, is a continuation of the past consolidation and coordination trends, but with a policy choice between a few multisystem holding companies versus a few pools made up of large independent systems. This involves consideration of the relative abilities of a single ownership unit or a committee of independent firms to efficiently manage the coordination of a large system as well as the potential adverse effects of greater market concentration in the power industry. In view of the discussions presented earlier, increasing mergers among the large systems does not appear to be the best policy, although a good case can be made for mergers among the smallest systems to achieve a minimum efficient size. Moreover, it has been argued that voluntary pools are easier to form and change or dismantle than are mergers (U.S. Federal Power Commission; 1970, Weiss, 1975). Hughes (1971) and Breyer and MacAvoy (1974) have emphasized the use of a few large, voluntary planning units with a Federal plan as a guide to a rational system. Despite the difficulties associated with achieving full coordination that were discussed in Section 5, it is possible for greater antitrust enforcement and reform of the regulatory institutions to make pooling a viable way in which to attain scale economies and the benefits of coordination. (See Breyer and MacAvoy, 1973 and 1974, for a critique of the FPC's role in promoting coordination. For broader critiques of commission regulation, see Phillips, 1969, and Trebing, 1976.)

A more important question, however, may have to do with the extent of consolidation rather than its form. That potential economic benefits of economies of scale can be obtained through consolidation of services, especially those that constitute natural monopolies, is generally recognized (see, for example, Cowing and Holtmann, 1976, Dajani, 1973, and Hirsch, 1968). It should be noted, however, that the natural monopoly criterion may be a more subtle concept than has previously been thought (see Baumol, 1977). To the extent that a monopoly is natural, the potential benefits accrue to the firm unless effective regulation transfers at least part of them to consumers and/or other parties. Primeaux (1975), among others, points out that regulated monopoly utilities do not always have lower costs than those facing competition. Thus the question of scale economies in electric power supply is more a question of degree than of existence. Indeed, until very recently, the econometric and engineering studies have been almost unanimous in their finding that significant scale economies exist over the range of existing system sizes. Barzel (1963, 1964), Cowing (1974), Dhrymes and Kurz (1964), Fuss (1979), Galatin (1968), Griffin (1977), Hughes (1971), Iulo (1961), Johnston (1952), Kirchmayer (1955), Komiya (1962), Ling (1964), Lomax (1952), McNulty (1956), Nerlove (1965), and Wilson and Uhler (1976) all report essentially L-shaped LRAC curves or increasing returns to scale that imply such cost behavior. Thus over the range of observations of these studies, there would appear to be no limit on system size in terms of unit cost declines. (See Cowing and Smith, 1978, for a review and critique of these and other studies.) Several proponents of restructuring the industry have assumed 5,000 MW to be the minimum efficient size for a system, and at least one engineering estimate reported that 25,000 MW would not exhaust scale economies (see Christensen and Greene, 1978, and Weiss, 1974). The LRAC curves suggested by these studies are shown in Figure 2. Breyer and MacAvoy (1974) used a system size range of 30,000 to 40,000 MW for their estimates of potential gains from coordination. A recent study (Christensen and Greene, 1976) using 1970 data that attempted to correct for the effects of holding companies on costs has reported that scale economies were exhuasted for firms generating in excess of 19.8 billion kWh annually, which implies a minimum efficient firm size of approximately 4,000 MW.* This finding is consistent with the results of a study (Huettner and Landon, 1978) using 1971 data and a different methodology. These investigators reported that minimum LRAC's were reached at a firm size of about 2,000 MW for all functions and for the generating function alone.† These findings are compared in Figures 3 and 4.

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*Christensen and Greene (1976) also reported that most of the cost reductions from 1955 (the year of Nerlove's study that they took as a point of departure) and 1970 was due to technological advances that shifted the long run average cost schedule downward but did not significantly change its L-shape; thus, scale economies were not a major factor.

†They also prepared benchmark estimates of potential unit costs from engineering data at the generating unit level and reported a similar figure for expected unit costs. This estimate is important due to the questions raised by Cowing and Smith (1978) regarding the distinction between ex ante and ex post; i.e., between input substitution choices made before technology

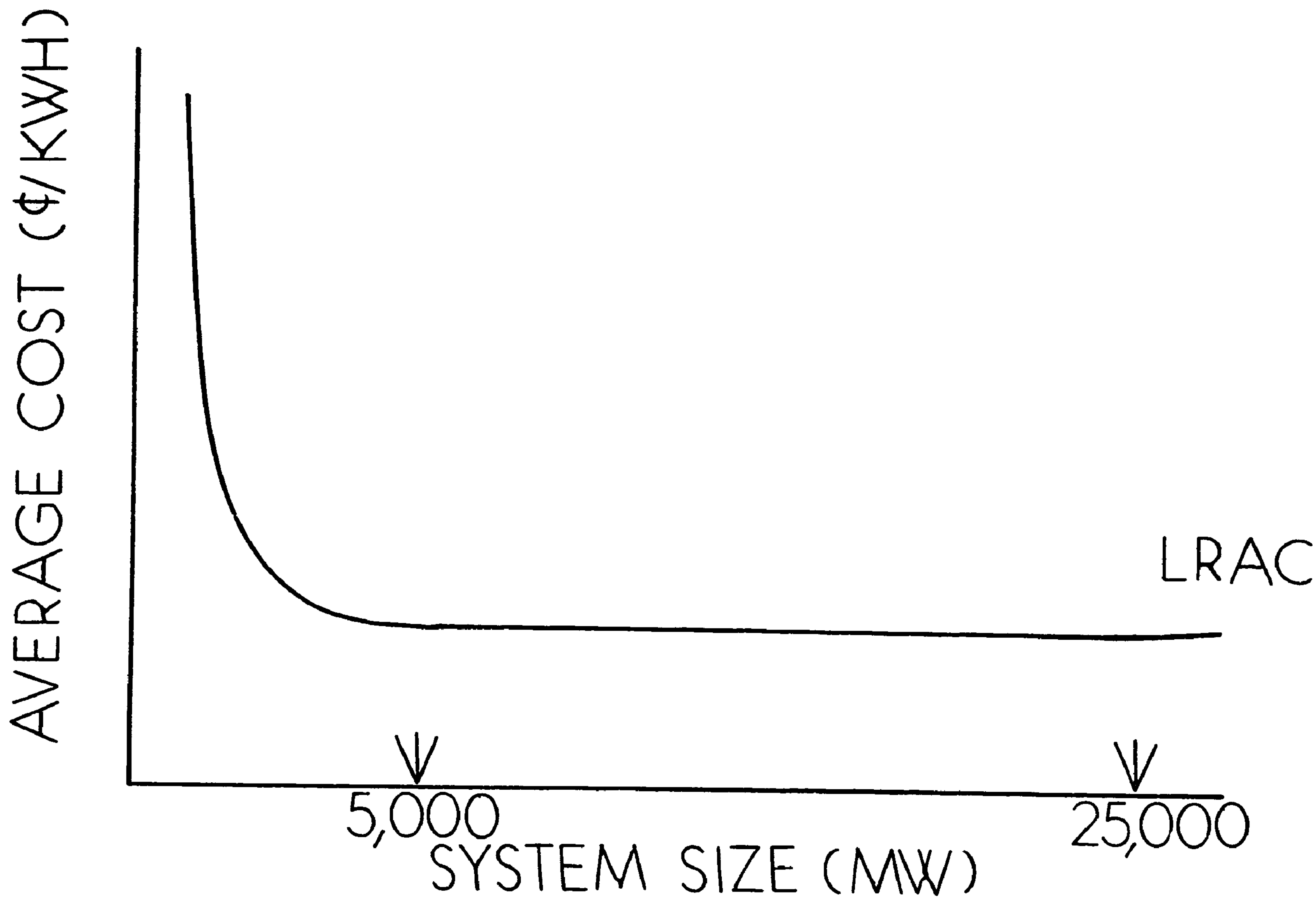

Figure 2. Suggested optimum system size as a result of scale economics.

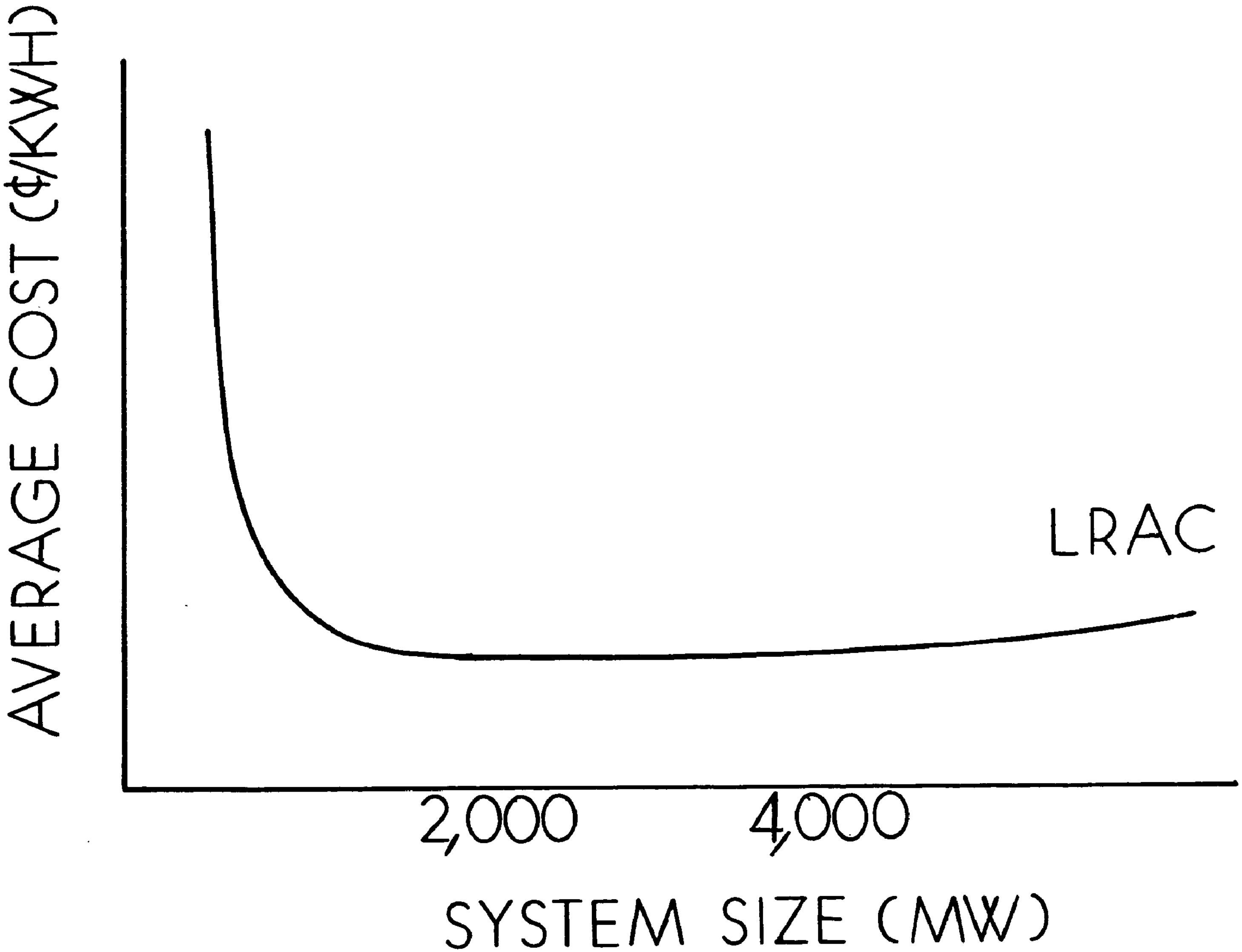

Figure 3. Alternative estimates of optimum system size by Huettner and Landon (1978) and by Christensen and Greene (1976).

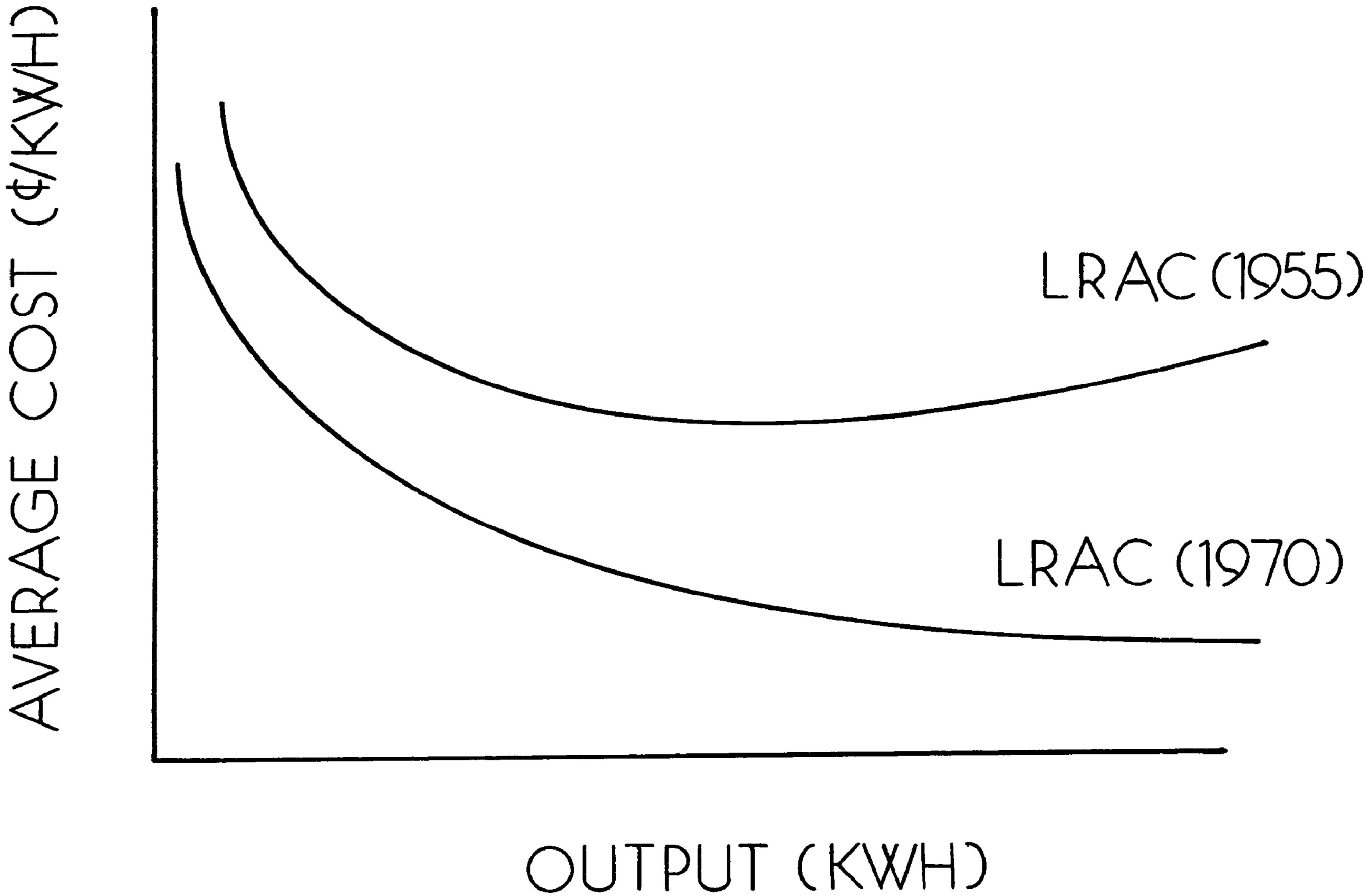

Figure 4. Cost reductions resulting from scale economies and technical changes, 1955-70. (Source: Christensen and Greene, 1976.)

The Huettner and Landon (1978) estimates, when combined with the Christensen and Greene (1976) study of coordination cost savings provide little support for the consolidation alternative. Indeed, the major disagreement between the two on minimum efficient size may be due to the way in which the effects of holding companies were accounted for. When members of holding companies were treated as independent firms, Christensen and Greene reported that unit costs in 1955 were minimized for the equivalent of a system size of 1,700 MW (as compared to the 4,000 MW obtained when holding companies were treated as a single unit). Unfortunately, Christensen and Greene did not make the same comparison for 1970. But if Huettner and Landon's criticism of Christensen and Greene is accepted on this point, the two studies are in even closer agreement. Furthermore, Huettner and Landon found no significant holding company effect on generation or total system costs.*

THE POTENTIAL FOR WORKABLE COMPETITION

The findings reported here do appear to support the alternative of restructuring the industry into competing systems of at least the minimum size necessary to exhaust scale economies, coupled with more reliance on antitrust remedies and/or a greater recognition of anticompetitive acts on the part of State and Federal utility regulatory commissions. Although the justification for the degree of horizontal integration that the largest systems have attained is called into question by the results cited above, the issue of vertical integration remains more in doubt. The incentive for any firm to integrate vertically involves a combination of potential reductions in costs and risks. That is, to the extent that a firm can control the terms and prices of its sales and purchases, it can reduce costs and insure markets and sources of supply. (See Kahn, 1971, pp. 256-64, for a good discussion of

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has been embodied in particular capital equipment and such choices after equipment design is complete. If input choices are restricted in the *ex post* situation, minimum cost solutions will differ from those obtained in the *ex ante* situation. It is also important to distinguish between what may be feasible according to engineering cost and production estimates, and what actually transpires for a variety of reasons having to do with managerial incentives, regulatory constraints, and other behavioral and institutional factors.

*Both studies have limitations, of course, but the "nontraditional" cost functions used by Huettner and Landon have been viewed with some skepticism by Cowing and Smith (1978) due to the lack of rigor with which they treated system behavioral objectives and duality. The latter concept refers to the correspondence between the estimated cost function and the underlying production process. Although the translog functional form used by Christensen and Greene appears to be more appropriate, Huettner and Landon maintain that their approach is better suited for the analysis of the effect of holding company membership on system costs. See the Appendix for more on alternative functional forms.

the economics of vertical integration.) Unless the firm is a monopoly, however, integration should benefit the consumer if the firm can produce a good or service internally at a cost that is lower than the price at which it can be purchased and if these cost reductions are reflected in prices. If a monopoly acquires a monopoly, the controlling firm can appropriate the profits of the other, which would not benefit the consumer. If the acquired firm is in a competitive market, integration could result in less competition to the extent that the other firms are excluded from buying from or selling to the controlling firm. On the other hand, vertical integration could be procompetitive if it improves the ability of the parent firm to compete, if it adds another competitor to the market for the services of the function being integrated, or if the mere threat of such an event affects the other market.

Regulation can force the controlling firm to pass the benefits of vertical integration on to the consumer. But the commission would have to examine carefully the allocation of costs between functions, especially if one is outside its jurisdiction, because the incentive exists to inflate transfer prices in order to show higher costs for regulatory purposes. It is also possible that the A-J effect under ROR regulation creates an incentive for vertical integration in order to increase the rate base. If the result was merely to raise costs without improving service, then integration would be inefficient.

Because the electric power industry is highly vertically integrated, especially with respect to generation, transmission, and distribution functions, any policy of opening up competition must consider the benefits and costs of divestiture and separation of these functions. If workable competition is to be fostered, vertical integration could be an impediment; on the other hand, separating major functions could result in higher costs and prices, albeit competitively determined.

Transmission as a Monopoly

General agreement seems to exist among those who have evaluated the competitive alternative that transmission has the greatest claim to being a natural monopoly. Thus proposals have been made (a) to regulate this function as a common carrier analogous to gas pipelines, or (b) to provide public transmission services (Breyer and MacAvoy, 1974; Kahn, 1971; Trebing, 1976; Weiss, 1975). Under either proposal, generation and distribution systems--private and public--would be free to compete among themselves for markets and for bulk power supplies.

The only econometric study to treat transmission as a separate function found no evidence to support the natural monopoly argument (Huettner and Landon, 1978). Indeed, the firms in the sample appeared to have diseconomies of scale over a wide range of output with a positive relationship between unit costs and miles of structure per customer. Moreover, holding company membership had no effect on costs.

Several qualifying remarks about this study are in order, however, as the authors point out. The capacity measure used was actually for generation, which could bias the results, but in an unpredictable direction. Line losses could bias results based on generation capacity in favor of scale economies. It is also possible that integrated systems view generation plant size and location as a tradeoff with transmission costs. Thus when total system costs are minimized, higher transmission costs may be more than offset by lower generating costs. Finally, the allocation of costs to the transmission function may be overstated because they are inherently unallocable (and thus arbitrary) and/or because of the regulatory distortions cited earlier (Huettner and Landon, 1978, p. 907).

Distribution

The distribution function has been studied to a greater extent than transmission, and there is some evidence to support exhaustion of scale economies at relatively low system sizes. (See the studies by Hellman [1972, p. 54], Huettner and Landon [1978], Meyer [1975], Neuberg [1976], Weiss [1975], and Wilson and Uhler [1976].) Neuberg (1976, 1977) found that the optimum size for distribution systems in his sample was between 85,000 and 230,000 customers, depending on the model used (the latter figure is for operating costs only). Assuming a 60-percent load factor, these results imply system sizes of approximately 370 MW and 1,300 MW, respectively. Most of Neuberg's estimates imply U-shaped LARC curves, leading him to conclude that the largest systems in his sample were too large, and that many others were too small. In terms of theoretical rigor, econometric technique, and the attempt to capture the peculiar nature of a distribution network in which geographic area and density of usage are cost determinants, this appears to be the best study to date.

The most recent study tells a somewhat different story, however. Huettner and Landon (1978) found that unit distribution costs follow an L shape in which scale economies appear to be exhausted at a system size of 2,600 MW, which corresponds to a system serving over 500,000 customers under the usual assumptions regarding load factors. These authors also reported a weak holding company effect on distribution costs and noted that the declining unit costs seem to justify declining block retail rate structures. Wilson and Uhler (1976), whose study was solely concerned with the cost justification of block rate structures, reported similar results for total, generating, and distribution costs.

As in the case of transmission, attempts to estimate distribution costs may be biased by the allocation of costs reported by integrated systems and by the technical question of the separability of functions. The latter has to do with whether or not the distribution stage (however defined) should be estimated as a separate function if vertical integration produces internal economies. (See Neuberg, 1976, and Courville, 1974, for discussions of the separability problem in this context.)

Still, both studies suggest that a policy of promoting competition among distribution systems would not be at as great a cost in terms of foregoing economies of scale as has been previously thought. Additional support for alternatives to greater consolidation is given by the findings that scale economies appear to be exhausted for system sizes of 2,500 MW for administrative costs and 1,700 MW for customer costs (Huettner and Landon, 1978). It was this last category of cost savings that Weiss (1975) suggested might be lost if vertical integration was reduced or eliminated.

Among other possible consequences of dismantling integrated systems are that single function systems may have greater risks in unregulated markets. However, if transactions costs are not excessive, and if access to markets and transmission lines is not blocked, the electric power industry should not find competition to be uniquely risky. As for planning, integration does not appear to be a necessary condition for increasing efficiency (Weiss, 1975). Indeed, Weiss argues that integration can result in suboptimal plant size and/or location decisions if firms attempt to serve captive distribution systems.

Other than the possible loss of cost savings associated with horizontal and vertical integration and pooling, the major impediments to a workable policy of competition appear to be the traditional ones of market structure and performance that concern the antitrust laws. Indeed, once the extent of the naturalness of the monopoly in this industry has been shown to be limited, most of the present barriers to entry and anticompetitive practices appear to be fostered by or sanctioned by regulatory authorities and/or legislation.* In addition to the court rulings and antitrust remedies that were discussed above (many of which were responses to the present system), changes in existing legislation could remove other impediments to competition. These include repeal of State antipirating laws that limit competition for customers in existing markets and laws that allocate exclusive service territories (Weiss, 1975).

Areeda (1972) also discusses the relevance of antitrust law to regulated utilities. Note that these recommendations would not necessitate complete deregulation, but would require a change in the criteria used by State and Federal commissions in regulating the industry. In any event, the antitrust laws would be available under deregulation.

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*Trebing (1976) cites three other separable arguments against competition: Systems too small to attract capital at reasonable costs or terms, regulatory lag, and shortages of fuel and capital. None of these arguments appear to be compelling or unique to this industry, however. For example, the significant size of the Southern Company and its subsidiaries (especially Alabama Power), has not insulated it from either capital attraction problems or regulatory lag (see Scott, 1976, for an evaluation of the industry's financing problems under the present industry structure). The last argument is, of course, a classic economic fallacy when one considers that the allocation of scarce resources is the economic problem that a competitive market system solves. Unfortunately, in recent years, market intervention has not only distorted efficient allocation of resources, but it has created shortages, which is not the same thing as scarcity.

PUBLIC SYSTEMS

Several aspects of the role of public systems must be considered. If transmission is indeed characterized by great economies of scale (which is unclear at this point), or if environmental and related concerns dictate non-duplication, then at least three alternatives suggest themselves: Unrestricted access to power supplies on economical terms, regulated common carrier status, and public ownership. On the other hand, public power subsidies should be eliminated if a competitive system is to be workable and efficient, with all competitors on the same footing (Weiss, 1975).*

More public ownership is also an alternative at the generation and distribution stages, but the potential for it seems greater for distribution systems through local option municipal franchise elections or the creation of power districts. (See Clemens, 1950, for a discussion of local, regional, and national issues, and Shepherd, 1965, for an evaluation of public enterprise performance in general.) If economic efficiency is the objective and if unit costs are decreasing over the relevant range of output (see Figure 5), public ownership could be a viable alternative to a regulated private monopoly because of the necessity for subsidizing the latter if prices are to equal the marginal or incremental costs of services.

Such a case is the classic natural monopoly (Figure 5), in which competition is thought to be unworkable. In this case, marginal cost pricing results in long-run losses to the firm because marginal costs are lower than average costs, which results in higher total costs than total revenue. The usual regulatory solution is to sanction average cost pricing; thus although monopoly profits are presumably avoided and output exceeds that of an unregulated monopoly, the result is not economically efficient. The obvious solution if efficient pricing is to be used is to subsidize the firms out of general tax revenues or to provide the service publicly.

Note that pricing schemes can be developed based on marginal costs that allow revenues to cover costs, but these have not been widely adopted. If a system is operating in a constant LRAC range, marginal cost pricing could allow normal profits, and public ownership would have to be justified on other grounds.

Of course, attainment of broader social goals than economic efficiency may be invoked to justify public ownership, which leads to equity versus efficiency arguments. For the purposes of this report, however, the focus will be on the relative efficiency of private versus public ownership and operation of electric power supply.

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*See Hellman (1972), Primeaux (1975), and Trebing (1976) for more on the existing competition between public and private systems. Primeaux (1978) has recently reported that he found no significant difference in the rate of capacity utilization (i.e., excess capacity) in markets served by a single utility and those served by two. This finding casts doubt on the natural monopoly argument used to justify monopoly franchises.

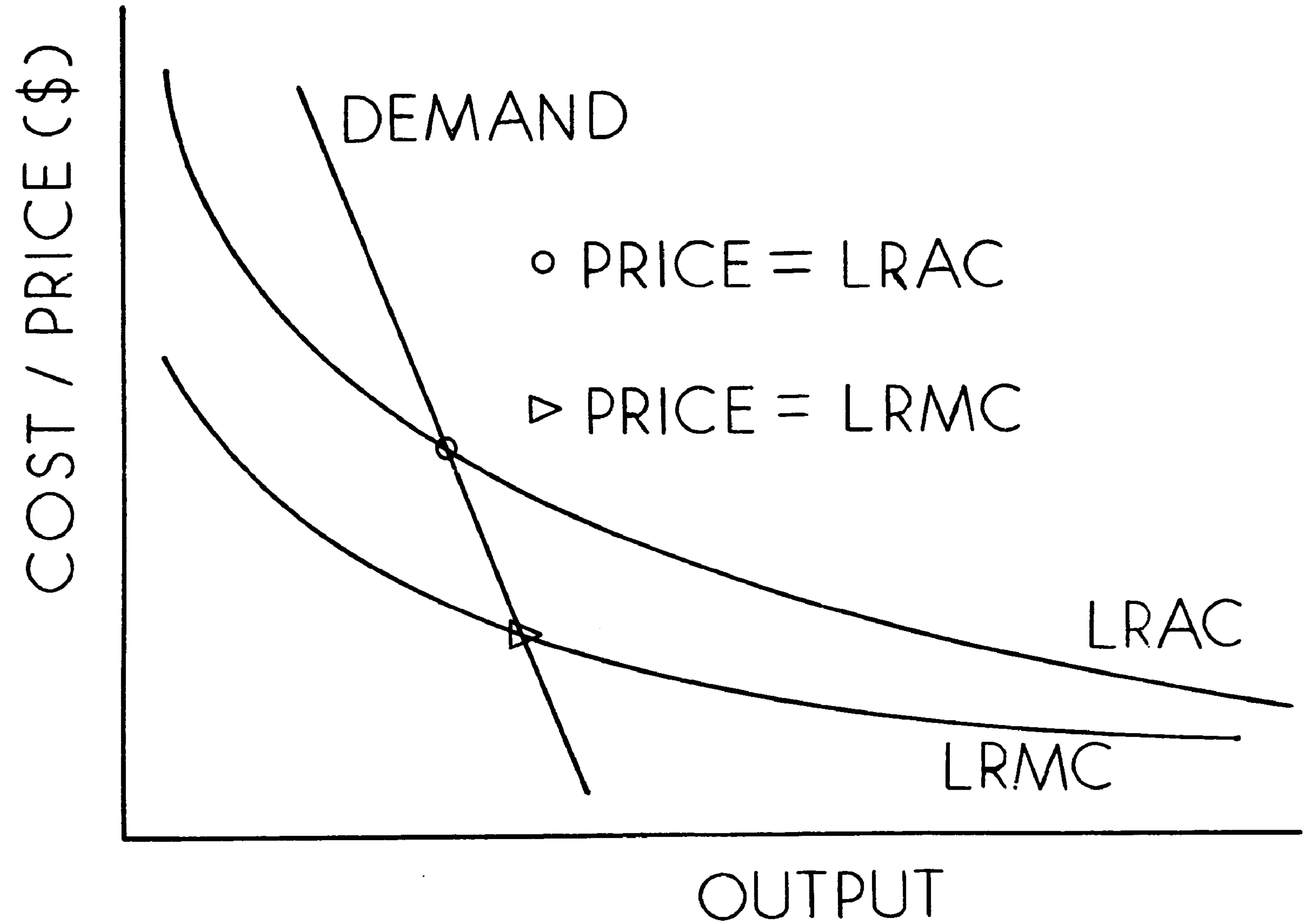

Figure 5. The natural monopoly case.

The logical reasons to expect differences in efficiency by ownership category include: subsidy of the public systems, differences in the quality of management and/or in managerial objectives and incentives, and the effects of ROR regulation on IOU systems. (See DeAlessi, 1974, for an evaluation of some of these arguments.) Two recent econometric studies have tested the hypothesis that type of ownership does explain cost differences among distribution systems. Meyer (1975) found that IOU systems had higher rates (except for larger industrial users) and higher costs than did municipals. The relative cost efficiency he identified for municipal systems was confirmed by the conceptually superior study of Neuberg (1976, 1977), who qualified his conclusions somewhat by pointing out that possible regulatory distortions may account for the difference rather than ownership effects (i.e., the A-J effect could have biased IOU costs upward). Neuberg's other possible explanations for municipal cost efficiency include IOU advertising and selling costs, differences in quality of management, arbitrary cost allocation and/or suboptimization with respect to the distribution stage by IOU's, and greater pressure on municipals to prove themselves in a pro-IOU environment. Unfortunately, the question of subsidy does not appear to have been adequately considered by Neuberg because of his use of the same cost of capital for both categories of ownership.

The implications of Neuberg's observation that many distribution systems are of less than optimal size are not clear. As the sample consisted only of regulated firms and municipal systems, the source of this inefficiency may be traced to one or more of the following: Regulatory distortions, deliberate suboptimization by integrated IOU's, or those political and economic forces that determine the geographic size of municipalities (which in turn dictates the market size). If economic efficiency is the criterion, then it is not apparent that public systems have a better record than private systems in the attainment of optimum size. Indeed, the record on consolidation of government services in general suggests that serious impediments to efficiency exist in the government sector (Hirsch, 1968). But on the other hand, regulation and public ownership (at least in practice) have the overt or covert purpose of facilitating internal subsidization of consumer groups. This use of price discrimination is difficult, if not impossible, to achieve in an unregulated competitive market. Moreover, discriminatory pricing is generally illegal under the antitrust statutes.

A mix of public and private power systems is likely to continue even if public policy is influenced by the emerging literature calling into question the natural monopoly assumption. If the current deregulation trend is more than the symptom of a short cycle in political economy, it is possible that competition will continue to be introduced into electric power markets. Such competition would require that consolidation be limited to the smallest existing systems and that existing regulatory institutions be reformed or replaced.*

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*Note that deregulation coupled with a tax on monopoly profits would not get at the problems of inefficient resource allocation and anticompetitive practices unless antitrust remedies were also used. Demsetz (1968) has proposed the alternative of competition for utility franchises by private firms, Competition in and for markets, in conjunction with spot and contract purchases, could be a viable alternative, but it places a heavy burden on recurrent contracting and, by implication, on the assumption that contract law behaves as if it seeks to attain efficient resource allocation. (See the works cited by Williamson, 1976, for the literature on the objectives of contract law and its role in facilitating market transactions.) The major objections to this approach appear to be concerns over price discrimination, the creation of greater risks, the nature of managerial incentives, and exceedingly complex contractual obligations. Furthermore, as Williamson (1976) points out, it is these factors that provide the incentives for vertical and, to some extent, horizontal integration, which could work against competition.

Areeda (1972) has predicted that eventually the courts will face challenges to government-sanctioned or created cartels and monopolies on new grounds. Previously, plaintiffs argued denial of due process or confiscation of property as a result of economic regulation; however, Areeda suggests success for the argument that such government actions constitute burdens on interstate commerce without being necessary to achieve their stated objectives. In view of the cases that have already touched on these issues, such success seems very likely. Whether actions of government units themselves (such as municipal power systems) will also be subject to this remedy is another question.

Most of the evidence on total and generation costs is for conventional fossil fuel plants. If nuclear generation continues to augment and/or displace this technology, the optimum size for a plant and system may well become larger than those reported in the recent literature; also, some of the advantages of pooling and other forms of close coordination may become greater. Joint ownership and staggered construction and plant location decisions take on even greater significance when the very large capital investment and the environmental and safety problems associated with nuclear technology are considered. On the other hand, the unit cost advantage that nuclear generation is now said to have over conventional plants could be partly based on subsidies and on an understatement of the true economic costs. The subsidies refer mostly to fuel fabrication, and the cost understatements have to do with environmental safety standards and the costs of meeting them.

Clearly more attention needs to be given to these arguments when the studies cited here are updated. Indeed, one of the reasons given for using generation cost data from no years later than 1971 is to avoid the effects that pollution control investments and mandatory conversion from coal may have on the results. Other complicating factors include the OPEC embargo and the resulting mandatory conversion from oil and gas. The present conversion of boilers from petroleum fuels to coal for conservation reasons is much costlier than the original conversion from coal to meet pollution standards.

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which could also eliminate excess profits. But see Trebing (1976) and Williamson (1976) for critiques of this proposal.

The uncertain future role of nuclear power generation aside, it appears that a case can be made for a rational bulk power supply system with many more than the 10 to 30 systems that have been suggested in the literature. In addition, the degree and extent of voluntary coordination (which could be a substitute for consolidation) necessary to facilitate scale economies may be less than earlier proponents had suggested. The argument for coordination may rest more on reliability and financing concerns than on the attainment of the very large system sizes that have been presumed necessary.

If this assessment of the power industry situation is accurate, then the transfer of the concept of a few large systems to the supply of treated water should be examined much more closely. Reliability and financing problems appear to be of a lower order of magnitude for water systems; thus the case for large systems should rest primarily on the existence of increasing economies of scale in the acquisition, treatment, and/or distribution of water. Future research should include the estimation of the cost-output relationships of treated water supply systems with respect to size and form of ownership as well as technology.

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APPENDIX

SUMMARY OF METHODOLOGIES USED IN ECONOMETRIC STUDIES OF ELECTRIC POWER SUPPLY

Most of the econometric studies cited in the text began with the assumption (explicit or implicit) that a production process can be described in general as

$$Q = f(\chi_i),\ i = 1, n \tag{1}$$

where Q is output, the χ_i are inputs, and the functional form represents a given technology. If input prices p_i are given, the cost function can be expressed as

$$C = \sum_{i}^{n} p_i \chi_i \tag{2}$$

with the χ_i assumed to be endogenous decision variables. Assuming the producer attempts to minimize equation (2) subject to (1), it is possible to obtain a unique cost function

$$C = g(Q,\ p_i) \tag{3}$$

if the production function has certain properties (Shephard, 1953). This duality between the production and cost functions allows inferences about one to be made from estimates of the other. If a linear model is specified for estimation purposes

$$C = \alpha_o + \alpha_1 Q + \sum_{i=2}^{n} \alpha_i p_i + \varepsilon \tag{4}$$

the error term ε is usually assumed to be randomly distributed, which implies no systematic differences among the production technologies used by the producers in the sample. Neuberg (1976) has argued that differences not captured in the inputs or their prices may be important cost determinants; thus he added a set of systems variables (s_j) to model (4)

$$C = \alpha_o + \alpha_1 Q + \sum_{i=2}^{n} \alpha_i p_i + \sum_{j=1}^{m} \beta_j s_j + \varepsilon \tag{5}$$

where the s_j represent kWh sold (s_1), miles of distribution line (s_2), and square miles of service area (s_3), and where output (Q) is the number of customers served. After evaluating a number of alternative families of functional forms for the underlying production function in terms of (a) their ability to approximate actual processes, (b) suitability for ordinary least squares (OLS) estimation, and (c) their ability to provide a simple test for returns to scale or scale economies, Neuberg selected the generalized Cobb-Douglas production function

$$Q = Q_o \prod_i \chi_i^{\alpha_i} \tag{6}$$

where returns to scale can be inferred from $\Sigma \alpha_i \gtreqless 1$. The dual to equation (6) can be expressed for two inputs, capital[1] (K) and labor (L),

$$C = C_o \, p_K^{\alpha_K} \, p_L^{\alpha_L} \, (\prod_j Y_j^{\beta_j}) \, e^{\gamma I} \, \varepsilon \tag{7}$$

where the Y_j are Q plus the s_j and I indicates an IOU or a municipal system. For estimation purposes, a logarithmic transformation of the data gives

$$\ln C = \ln C_o + \alpha_K \ln p_K + \alpha_L \ln p_L + \sum_j \beta_j \ln Y_j + \gamma I + \varepsilon \tag{8}$$

Returns to scale are decreasing, constant, or increasing as $\sum_j \beta_j \gtreqless 1$.

To test for a U-shaped or L-shaped average cost curve, Neuberg estimated

$$\ln AC = \ln AC_o + \alpha_K \ln p_K + \alpha_L \ln p_L + \sum_j \beta_j \ln (s_j/Q) \tag{9}$$

$$+ \phi \ln Q_j + \rho (\ln Q)^2 + \gamma I + \varepsilon$$

and tested for $\rho = o$ versus $\rho > o$. A point estimate of optimum system size, $\hat{Q} = e^{-\hat{\phi}/2 \hat{\rho}}$, was obtained by differentiating (9) with respect to Q and solving for $\hat{Q}$.

A more general production function was used by Christensen and Greene (1976, 1978). The translog function is

$$\ln Q = \ln \alpha_o + \sum_i \alpha_i \ln \chi_i + 1/2 \sum_i \sum_j \beta_{ij} \ln \chi_i \ln \chi_j \tag{10}$$

If $\beta_{ij} = o$, then $\ln Q = \ln \alpha_o + \sum_i \alpha_i \ln \chi_i$, which is the Cobb-Douglas form.

If $\sum_i \alpha_i = 1$ and $\sum_i \beta_{ij} = \sum_j \beta_{ji} = \sum_i \sum_j \beta_{ij} = o$, there are constant returns to scale. The translog cost function estimated by Christensen and Greene was

$$\ln C = \ln \alpha_o + \alpha_Q \ln Q + 1/2\ \beta_{QQ} (\ln Q)^2 + \sum_i \alpha_i \ln p_i \tag{11}$$

$$+ 1/2 \sum_i \sum_j \beta_{ij} \ln p_i \ln p_j + \sum_i \beta_{Qi} \ln Q \ln p_i$$

$$+ \sum_i \phi_i D_i + \varepsilon,$$

where the D_i are a set of dummy variables to control for organizational form, regional effects, etc. A maximum likelihood procedure was used to estimate equation (11) together with the cost share equations for each input

$$s_i = \alpha_i + \beta_{Qi} \ln Q + \sum_j \beta_{ij} \ln p_j \tag{12}$$

in order to gain more degrees of freedom and avoid the multicollinearity problems likely with OLS estimation of (11) alone. It was the latter problem that led Neuberg to prefer the Cobb-Douglas over the translog function. The extent of scale economies depends on $(1 - \frac{\partial \ln C}{\partial \ln Q})$ being greater than (economies) or less than (diseconomies) zero.

The nontraditional approach taken by Huettner and Landon (1978) consisted of OLS estimation of

$$AC = \alpha_o + \alpha_1 \ln K + \alpha_2 (\ln K)^2 + \alpha_3 \ln U + \alpha_4 (\ln U)^2 \tag{13}$$

$$+ \sum_i \beta_i D_i + \alpha_5 p_F + \alpha_6 p_L + \varepsilon,$$

where K is a measure of capacity, U is the capacity utilization rate, p_F and p_L are prices of fuel and labor, respectively, and the D_i are dummy variables for the effects of region, organizational form, fuel mix, etc. The squared terms were included as a test for the shape of the average cost curve, and it was assumed that system output could be expressed as Q = KU.

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GLOSSARY

Coordination or Pooling: The coordination of activities by power systems. This practice can range from the sharing of information on maintenance schedules and capacity expansion plans by independent systems to the operation of systems under common holding company ownership with centralized management and dispatch of power from the least-cost plant in the system. The latter is often termed a "tight pool," and pooling itself is usually associated with attempts to reduce operating and investment costs through relatively formal contractual arrangements. The less formal arrangements constitute a broader aspect of coordination (e.g., the Electric Reliability Councils or other area coordination organizations). The primary distinction among these various categories of organizations is the extent of contractual obligation of the member systems.

Interconnection: The physical connection of two or more systems by transmission lines.

Interchange: The purchase and/or sale of electricity by two or more systems, either on an emergency or a regular, contractual basis.

Reliability: The frequency and duration of service disruptions and voltage fluctuations, often expressed in terms of probability of failure.

Wheeling: The transfer of electric power between two systems by way of the transmission lines of one or more intermediate systems. This process usually involved displacement, in which the intermediate system provides power to the final user and replaces it with power from the originating system.

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16. ABSTRACT

This two volume report examines the present and future demands and costs for residential water in view of the new requirements for water quality standards under the Safe Drinking Water Act of 1974 (PL92-523) Volume 2 (This volume) investigates consolidation in the electric power supply industry as an example of a possible method of offsetting the increased costs of water treatment that will be incurred under the new Federal regulations. The structure of the power industry is examined and the history advantages, and cost benefits of coordination are evaluated. Several alternatives to the present system are considered, including consolidation of existing systems, encouragement of competitive markets, and public ownership of generation and transmission facilities.

The most significant product of this research effort is the analogics that can be drawn between the history of regionalization in the electric power industries and the future for Drinking Water supplies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Consolidation	Regional Planning		13B
Economics	Urban Development		
Electricity	Urban Planning		
Financing	Utilities		
Planning	Water Consumption		
Power Lines	Water Distribution		
Power Plants	Water Supply		

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