

WORKING PAPER  
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

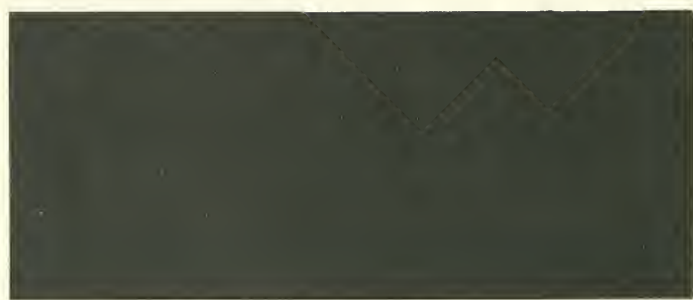
ECONOMIC PRESCRIPTIONS FOR DEVELOPING  
THE REGULATED INDUSTRIES\*

*Sno*

505 - 71

*MacAvoy*  
Paul W. MacAvoy  
Professor of Economics, Sloan School of Management  
Massachusetts Institute of Technology

MASSACHUSETTS  
INSTITUTE OF TECHNOLOGY  
50 MEMORIAL DRIVE  
CAMBRIDGE, MASSACHUSETTS 02139



1971  
BOSTON LIBRARY

ECONOMIC PRESCRIPTIONS FOR DEVELOPING  
THE REGULATED INDUSTRIES\*

Sno

505 - 71

*w.c.*  
Paul W. MacAvoy  
Professor of Economics, Sloan School of Management  
Massachusetts Institute of Technology

\* This is one of a series of papers on regulation in the energy industries supported by the Brookings Institution Program of Research in the Regulated Industries. I am grateful to Brookings, and to the Ford Foundation for supporting Brookings in this endeavor; also to William Capron of Harvard University and Harvey McMains of American Telephone and Telegraph Company for their wise counsel.

HD28  
, m414  
no. 505-71

RECEIVED  
JAN. 26 1971  
M. I. T. LIBRARY

The regulated local monopolies in gas, electricity and telephone service have encountered "shortage" problems in the last two or three years, and they have little chance of solving these problems in the expected manner with large transfusions of new investment. The shortages have not been measured on any economic standard, but if a quality index were used to deflate physical output, then "quality output" would probably register at about the same level now as three years ago in all three industries in the larger population and industrial centers. Most evident, there have been queues for new gas and telephone service in Pennsylvania, New Jersey, and Illinois, and interruptions in peak-load electricity service in four Eastern Seaboard states. These events have been no more than symptomatic of capacity shortages in telephones, fuel inventory shortages in gas, and both capacity and fuel shortages in electricity. The queues in gas have been indicative of shortages of new field reserves estimated to be in the range of 25 to 50 per cent of new discoveries in the last five years; as the "short" inflows continue, the inventory shortage now approaches 25 per cent.<sup>1</sup> Delays in telephone installations have been indicative of shortages in switching capacity of 10 per cent or more of peak demands at least in a half-dozen large states. The interruptions in electricity service have

---

<sup>1</sup> Cf. P. W. MacAvoy "The Regulation-Induced Shortage of Natural Gas" The Journal of Law and Economics XIV, #1 (1971), and Fortune Magazine May 1970, page 266.





indicated shortages of fuel inventories of as much as 50 per cent, and of capacity of as much as 10 per cent.<sup>1</sup>

There are economic policies for clearing markets that might ease these problems, but the prospects for using them to achieve complete solutions are slim indeed. The economic decision rules for peak-load pricing -- in effect, setting prices which themselves clear excess demand on the peak and deficient demand off the peak -- have withstood analytical criticism and have been applied with significant effect in Europe.<sup>2</sup> They could be used here. Following these arguments, prices could be increased for final services where there is excess demand, and the higher final output prices then would serve as the basis for higher bid prices for the scarce input resources. This plan should work to clear fuel markets of excess demands; in particular, elimination of Federal Power Commission ceiling price regulation in gas field markets would allow competitive markets for gas to act in this way, so as to both add to quantities of gas supplied and reduce those demanded. The market-clearing price increases would be substantial; those in gas, under the most optimistic conditions (assuming that there is never any holdover excess demand from previous years), would be close to 100 per cent of last year's regulated price level.<sup>3</sup> As a consequence, there would be substantial

---

<sup>1</sup> Cf. Fortune Magazine, May 1970, page 70, where fuel inventories are assessed to be half the "normal" levels on the East Coast, and capacity peaking margins to be closer to 5 per cent than to 15 per cent. These are crude estimates, at the best.

<sup>2</sup> Cf. J.R. Nelson Marginal Cost Pricing in Practice (Prentice-Hall, 1968).

<sup>3</sup> Cf. P.W. MacAvoy "The Regulation-Induced Shortage of Natural Gas" op. cit.



income gains of producers and losses of consumers; but the plan would work because it would bring forth substantial additional (now extra-marginal) supplies within a year. There might be less success from raising prices to relieve shortages resulting from deficient capacity. As a matter of course, Consolidated Edison in New York City could clear excess peak load electricity demand by raising prices until consumers went away. There would be some set of prices at which this would work, also. But the reasons for consumers going away might not be "acceptable," particularly if industries respond to rising electricity prices with work stoppages. Here the effect on GNP and employment of wide swings in energy prices would be so adverse that political decisions would probably have to prevent these attempts to clear markets. The transfer of income from the consumer to the Edison Company might be politically unacceptable as well, unless there is some final output effect -- unless producers' profits or quasi-rents are an additional important stimulus to new investment. There is no analytical reason for this to occur, however, when the producing company is a regulated and protected monopolist, so that the "supply response" rationale for enduring the short term income effects of price increases is not compelling.

The long run economic decision rules center on making capacity additions so as to increase output to the level at which prices equal long run marginal costs. No one has estimated how much additional investment would be required to accomplish this. New capital outlay



for telephone switching and transmission will have to come to more than \$100 billion in the next 15 years with the present pricing scheme, and outlays in the electricity industry for production at present prices, but just for generating equipment alone, will have to be more than \$400 billion between 1971 and the year 2,000.<sup>1</sup> The investments in finding and developing new fuel resources will have to exceed \$300 billion.<sup>2</sup> These outlays would only be a minor portion of the costs of capacity to eliminate excess demand; increased use of land, air and water resources around and in urban regions would be required as well, and the costs of these resources have not been entered into this accounting. These costs have not been included in forecast capital and fuel expenditures because, in the absence of well-functioning markets for the environment, consumers as a group bear most of them. They are extraordinarily difficult to calculate because of the absence of markets either to purchase those resources, or to do away with the effects of industrial use of them; there is certainty only that they are going to be large enough to have an effect on political decisions.

The required "internalization" of these natural resource costs by consumers puts great pressure on the national political leadership not to solve excess demand problems. Governments now hear more and

---

<sup>1</sup> Cf. P.W. MacAvoy Economic Strategy for Developing Nuclear Breeder Reactors (M.I.T. Press, 1969).

<sup>2</sup> Fortune Magazine, op. cit.



stronger objections of minority groups against the construction of new generating plants by electricity companies, or new pipelines by gas companies, and the nature of the response most often now is to delay or disallow the investments. The final result of rulings of this nature can well turn out to be a state of permanent excess demand. In economic terms, regulatory prohibitions against the use of natural resources by energy and communications companies could prevent the achievement of levels of investment required to clear markets at marginal or average cost prices.

There is an alternative long run economic plan for relieving excess demands. In face of prohibitions against the use of natural resources, those making research and development plans could orient new work towards innovations in resource-replacing capital equipment. There are candidate projects for developing such types of equipment. The promising avenue for research to follow is not towards finding ways to estimate and charge the costs of land and water rights, although this work is worthy even if it looks impractical at present, but rather to find new technology in capital equipment that relieves the demands for these resources.

#### The Promising But Unproven Technologies

The technology in the energy and communications industries would seem to be little different now from that some years ago. This impression is not easy to substantiate. The best analyses of technology,





in the reports and papers of the national laboratories such as at Oak Ridge and Los Alamos, and of the university-affiliated government laboratories, are testimony to the need for precise description in order to make new developments; but none generalizes on the extent of innovation in new equipment and systems in these industries. The lack of review material itself seems to be testimony, however, to how very little new application of science there has been. On the engineering measures of efficiency, there seems to have been substantial progress, particularly from higher load factors or larger scale for the single producing unit, resulting in productivity increases of 3 per cent to 5 per cent each year. Cost reductions have been captured by scale changes and reliability improvements, but there have been few new commercial applications of engineering science.<sup>1</sup> On other dimensions there has been little progress; the techniques used for energy conversion in both sound transmission and electricity production are the same now as they were 50 years ago. These are natural resource using, in the sense that there were alternative techniques also available 50 years ago that, if used, would have resulted in substantially greater capital investment and less fuel, air, and water utilization. The near future techniques will continue to be the same resource using technologies, given that the plans for expansion of the major companies in these industries now are for

---

<sup>1</sup> Cf. W.R. Hughes' chapter on electric power in Technological Change in the Regulated Industries, W. Capron, editor (Brookings, 1971).



more of the same systems on a larger scale. Progress would have been the development of new technology that, when put in operation, cost no more in total outlay but much less in natural resources.

There are some development projects now operating at low levels that could accomplish this. They differ greatly in the problems to be solved -- some are in the behavior of materials at  $4000^{\circ}$  F or at  $-450^{\circ}$  F, while others have been encountered in the behavior of large scale or complex systems. All have histories of promising first-stage development results in one or two companies, but a lack of commitment to second-stage test modules or prototypes, where the commitment involved large financial outlays and inter-company co-operation. There are four to be considered here. (1) the generating of electricity by MHD (Magnetohydrodynamics), a technique centering on obtaining current from passing a gas at  $4000^{\circ}$  F through a magnetic field, has had a long laboratory history and commitments of several million dollars through the half-scale prototype stage. (2) electricity from the breeder reactor has been produced by plants beyond the prototype stage and at the full-scale experiment stage, but only in one very specific coolant technology receiving contract grants from the Atomic Energy Commission. The breeder reactor is a steam generator with a difference -- a reactor that uses the "fast" or unmoderated fission process to produce both heat energy and high productivity plutonium at the same time. The development problems center on maintaining dynamic control of the fission process -- controlling



random displacement of temperature from equilibrium so as to prevent melting of the reactor core -- but there are problems as well of systems development in the cooling medium that are critical for plant economics. These latter problems differ for a helium-cooled system from a liquid sodium-cooled system, and the A.E.C. has shown interest in solving only the liquid sodium reactor's problems. (3) superconductivity is a technique for obtaining electricity with less of certain natural resources, in this case resources not in generating but in transmission of electricity. Development projects here seek to deliver electricity without line loss over long distances on enclosed rare-metal conduits at  $-450^{\circ}\text{F}$ . They are stalled on funding and organizing a full-scale prototype. (4) the new technology in communications is capable of passing through three stages, and whether it does is merely a matter of very extensive expenditures on development. The initial stage is in the development of large scale systems combining digital switching equipment and satellites efficiently. There are many combinations in systems engineering that have to be tried for efficiency and for compatibility with present systems. The second stage is the integration of "narrow band" telephone with "broad band" video to provide two-way 50 to 100 channel unified picture and voice communications in every household. The third and farthest stage is completion of technical developments that will extend the useable electromagnetic spectrum for communication to the millimeter wavelengths. At each stage there has to be extensive experimentation with configurations



of data networks, telephone networks, new digital switching centers, and satellites. The experiments call for large numbers of different prototypes which have yet to be undertaken and funded.

These technologies have promise in dimensions not measured five years ago. The MHD generator and the breeder reactor are expected to produce electricity at costs comparable to those experienced in new fossil fueled generators in the middle 1960's. But this is without taking account of the almost complete elimination of the social costs of using the air and water resources around the producing plants and the land resources devoted to mining fossil fuels. The MHD generator expects to achieve a 50 per cent increase in thermal efficiency as a result of higher temperatures, and expects to operate most efficiently in a closed cycle, with consequent significant reductions in thermal water pollution and in air pollution. The gas-cooled breeder also operates on a closed cycle, and it reduces demands for enriched uranium, to the point that present stockpiles of uranium mining and manufacturing residue ought to serve as the basic "breeding" fuel supply for the rest of the century in this country. The superconductivity development program is not as promising, since the costs for replacement of present above-ground long distance transmission lines with below-ground superconductivity lines will be substantial. But underground superconductivity transmission would release land for other uses, as underground gas transmission does at the present time, and such transmission would also increase useful





output of electricity from fuel and capital outputs by more than 10 per cent. The three-stage communications development program would increase the productivity of bandwidth and telephone line transmission. It is possible to plan for exponential 10 per cent demand increases to the year 2,000 with present configurations of bandwidth, energy and land resources devoted to vastly expanded telephone, data and video home communications.

#### The Economics of Development

These technologies will require money, time and an economic strategy to become effective. How should the development programs be organized, and what are the sources and amounts of required expenditures?

The answers so far have been provided by the electrical equipment manufacturers, the Atomic Energy Commission, and Bell Laboratories. They have provided the funds and done the work themselves. This state of affairs raises more questions than it answers. Are these organizations the right size and do they have the maturation for making decisions on the relative efficiency of alternative development projects? Should the development of each of these new technologies become the responsibility of Government, or industry consortia, or only of certain private companies, on grounds that goals will be reached sooner, and at lower costs?



The answers are a matter of extensive research, and the information required for this research has not been made available by those now involved in development projects. The information required is quite specific to the economics of parallel research. This economic analysis -- arriving at policies as firm as those on pricing described above -- begins with assuming that there are numerous competing projects each promising to develop these new technologies, and these must be eliminated by sequential decisions so that, at the last stage of development, the least cost project in each technology survives. This requires  $m$  parallel projects at the initial stage, from which  $m \geq 1$  are chosen up to the last stage -- but only if cost estimates improve at each stage. More precisely, two improvements are required. First, the expected value  $E(c/c_n, c_{n+1}) = c_{n+1}$ , where  $c$  is the final estimate of demonstration plant cost and  $c_n, c_{n+1}$  are estimates of this same cost but at successive earlier stages  $n$  and  $n+1$ . Second, the squared errors of successive estimates must diminish, or  $E(c_n - c)^2 \geq E(c_{n+1} - c)^2$ .<sup>1</sup> The decision then is to choose first the project with the lowest forecast costs, and second any other project for which the "looking costs" are less than expected subsequent cost reductions from being able to select the best from multiple projects after one more stage.<sup>2</sup>

---

<sup>1</sup> Cf. T. Marshak, et al. Strategy for Research and Development (Springer-Verlag, 1967).

<sup>2</sup> The "looking costs" are the costs of running that project one more period. Cf. T. Marshak, op. cit., page 245. This does not hold for  $m > 3$  -- a "striking example of the ability of analysis to refute intuition."



To make these decisions on the breeder reactor would require the development companies to reveal recent changes in design study estimates of the costs of developing breeder fuel and capital. These changes, calculated in a roughly comparable way for different coolant technologies in the first non-breeder round of development in the 1950's and early 1960's have been made known after the fact. They show clear cost savings from parallel research and development, of up to five coolant types; <sup>1</sup> now they have to be calculated a priori for the breeder round of development. Then normative propositions can be formulated on the efficient number of parallel breeder reactor projects.

Even at this preliminary stage of economic analysis, however, some propositions on the breeder and on other new technologies can be anticipated. Orders of magnitude of costs, and the nature of research, must imply that the work will have to be done by an organization larger than a producing industry. The costs of developing any one of these new technologies will exceed more than one billion dollars, even if only a single (non-parallel) project is undertaken. The estimated costs of research and development for a liquid sodium-cooled breeder reactor are now between \$1.3 billion and \$3.2 billion, while those for a gas-cooled fast breeder reactor are between \$1.0 and \$2.8 billion. The optimal combination of parallel projects will

---

<sup>1</sup> P.W. MacAvoy Economic Strategy for Developing Nuclear Breeder Reactors, op. cit., Appendix A.



likely cost from \$2.2 to \$4.6 billion.<sup>1</sup> Those for the other technologies extolled above may not be quite as large, although this may be the case because it is still early in the history of making cost estimates on MHD or digital switching. Parallelism seems promising in each technology. There are numerous projects proposed towards final construction of an economic demonstration plant in each of the new technologies; the breeder technology may boast three, the MHD technology two, and the digital switching-satellite combination more than either of these. The projects will realize substantial changes in forecast costs and performance early (in the sense described above), at least to the full-scale prototype, so that there should be more than one project at least at the next few stages of development. Given the many requirements and the necessity of parallel projects, no single company could carry on the optimal number of projects in any one technology. There has to be a consortium of buyers, producers, or governments because of (a) the large scale of single projects, (b) the total cost savings likely to follow from taking on more than a single project, (c) the necessity for non-market decisions in the choice among duplicative projects of the final single project.<sup>2</sup>

---

<sup>1</sup> P.W. MacAvoy Economic Strategy for Developing Nuclear Breeder Reactors, op. cit., page 47.

<sup>2</sup> Marshak, in his discussion of a "decentralized" organization, requires that the many approaches be compared at each stage by a single decision maker. T. Marshak, op. cit.





The only organization presenting itself as such a consortium at this time is the Federal Government. No other operates at such a large scale in R&D that it does not face the risk of default on all its obligations if parallel approaches in a new technology default. The consortium-Government here could possibly operate as an insurer and banker, by funding research to be carried out by private companies; it might be capable, given the risk that internal politics will protect projects, of making unbiased comparisons of costs at each stage and then weeding out the higher cost approaches. The best way of establishing this presumption is to compare the problems of the Government with those of alternative consortia.

The electricity or gas retailing industries, as a consortium, could form a collection of sub-organizations to do research and development. But would the consortium managers likely choose the optimal research path? Capital markets are not now perfect enough to provide them with funds to do enough research -- at least not enough relative to the Government consortium with its balanced portfolio of many other R+D projects. Also, they would not organize correctly. Since individual demands for new technology by the retailers would differ over a wide range -- depending on buyer's scale and the prices of fuels at his location -- an averaging process would have to be applied to all demands. The weighting in the consortium would probably have to account for large numbers of small firms, so that the "average buyer's demand" for new technology would call for a smaller



scale than warranted by new "largest buyers' demands." The second demand would not be chosen, even though offering lower unit costs for the final consumer, in costs of natural or other resources. Rather than the new technology changing market structure, it would be fitted to the prevailing market structure. This consortium might choose a costlier approach for the good of members, as well, where this approach promised higher costs of those factors on which a "regulated rate of return" could be made.<sup>1</sup> Even though more capital and less natural resources can be called for from the new technology, the prejudice of the buyer in favor of "return-earning" capital does not guarantee that this consortium achieves the right balance. There is considerable doubt that the companies on the buying side of markets for energy equipment could as a group decide the least-cost staging of multiple approaches to new technology in this industry.

The producers of equipment themselves could form a consortium to carry on research. Here the motivation for cost reductions would be strong, and the scale of research would at least be in keeping with the large scale of the firms on the producing side of these industries. There would be serious problems, however. Given that each company would specialize in a project, the "weeding-out" of projects would require that some companies fail to complete their programs. In effect, the consortium would be required to fail its members and such decisions

---

<sup>1</sup> Cf. P.W. MacAvoy Economic Strategy for Developing Nuclear Breeder Reactors, op. cit., Chapter 3.



would be more or less difficult to make, depending on the way in which the organization was structured. The decisions might well depend upon being able to make side payments to failed firms, and these payments would raise other serious problems. The existence of an industry-wide organization to control research output and render side payments to member firms makes collusion on final production of new equipment possible, and even probable. The economy-wide losses from collusive prices can be greater than the gains from following the consortium's efficient research plan; in the case of developing breeder reactors, these losses appear to be half of the total gains from the breeder and substantially greater than the savings from eliminating duplicative research.<sup>1</sup> In any event, the (alternative) Government consortium would not present the problems inherent in research collusion among producers.

The exception is perhaps the telephone industry. With the retail telephone companies organized into the "American Telephone and Telegraph Consortium" covering most of the industry, there is a strong decision maker with coverage comprehensive enough to assess the various system development projects in Bell Laboratories, The Western Electric Company, and operating companies throughout the country. The scale of projects, given AT&T's access to the broadest non-governmental capital sources, is likely to be close to that of

---

<sup>1</sup> Cf. P.W. MacAvoy Economic Strategy for Developing Nuclear Breeder Reactors, op. cit., Chapter 4.



the Government consortium itself. The integration of development into a single company providing the final equipment does not create the "collusion problem" if the regulatory agencies control the ill-effects from a single source of supply in this industry. There is some basis for constructing "m" approaches to digital switching configurations within the jurisdiction of Bell Laboratories, for example, and expecting internal cost reviews to lead to reductions in this number until the least-cost approach remains at the last stage. There are still problems, however. The choice of projects may be influenced by regulation on the basis of return on capital; even if, once again, the overemphasis on capital is appropriate, there is no way to tell when it is excessive. Also, the choice of projects may be influenced by whether the development work is done within AT&T or outside, with those done inside favored because they add to costs providing a regulated return. Given that much of the Government-sponsored research on satellite technology is both well ahead of and outside of AT&T, the location of the "producers' consortium" within AT&T might result in too little new space technology and too much new earth technology.

The proper organization depends centrally on costs, and on the importance of parallelism in development. More than one approach most likely will be shown to be optimal for cost or demand reasons for the next few years, in each of the technologies mentioned. One





company probably cannot afford to complete the new technology.<sup>1</sup>  
This seems most probable, in the energy industries at least; but it is still a bit early to assert that the electricity and gas companies ought not to do any research and development. It is only likely that the Government could and should do it, probably by funding a number of company ventures in competing projects in any one technology and then choosing the best of these.

Even here, the proposition as to best organization is not firm and precise, since the "Federal Government" includes The Federal Power Commission, The Atomic Energy Commission, The Federal Communications Commission, and the various Power Administrations in the Department of the Interior, each with its own constituency. None of these is the institution for efficient R+D. If the Atomic Energy Commission were to choose projects, given its constituency in the steam boiler industry, little work would be done on superconductivity and even less on digital switching or satellites. The Federal Power Commission's long experience with controlling entry and prices in the gas transmission industry would not prepare it well for choosing among reactor development schemes. The best organization for making R+D decisions would be versed in science, and would be located in the

---

<sup>1</sup> The argument made for parallel research in the study of the breeder reactor was that a portfolio of projects would produce a variety of products, all of which would be demanded at levels justifying the additional expenditures. There were not enough data to evaluate "pure parallelism" on one specific output.



Government so as to be able to make comparisons on the use of resources across technologies without answering only to one constituency in one technology. The organization should have responsibility for all R+D expenditures on energy and communications technology. If the assertions made here are correct on what has to be done to eliminate excess demand in energy and communications, and those on the scale of R+D are also correct, then the Executive Office of the President could and should form this organization very soon.

NOV 11 '70

10-12

W 7 '75



