SALINE WATER CONVERSION PLANT

by

William F. Hederman, Jr.
# CONTENTS

## Section

<table>
<thead>
<tr>
<th>I. INTRODUCTION</th>
<th>G-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>II. POLITICAL AND ORGANIZATIONAL BACKGROUND</td>
<td>G-2</td>
</tr>
<tr>
<td>Legislative History</td>
<td>G-2</td>
</tr>
<tr>
<td>Demonstration Authorization</td>
<td>G-3</td>
</tr>
<tr>
<td>Organizational Relations</td>
<td>G-3</td>
</tr>
<tr>
<td>III. TECHNOLOGICAL BACKGROUND</td>
<td>G-5</td>
</tr>
<tr>
<td>Process Selection</td>
<td>G-5</td>
</tr>
<tr>
<td>The VTE Process</td>
<td>G-8</td>
</tr>
<tr>
<td>IV. FEDERAL GOALS</td>
<td>G-10</td>
</tr>
<tr>
<td>The Congress</td>
<td>G-10</td>
</tr>
<tr>
<td>The President</td>
<td>G-10</td>
</tr>
<tr>
<td>The Office of Saline Water</td>
<td>G-11</td>
</tr>
<tr>
<td>Other DOI Agencies</td>
<td>G-12</td>
</tr>
<tr>
<td>Industry</td>
<td>G-12</td>
</tr>
<tr>
<td>Target Audience</td>
<td>G-13</td>
</tr>
<tr>
<td>V. INITIATION AND SELECTION</td>
<td>G-14</td>
</tr>
<tr>
<td>Design Contractor</td>
<td>G-14</td>
</tr>
<tr>
<td>Site Selection</td>
<td>G-14</td>
</tr>
<tr>
<td>Construction Contractor Selection</td>
<td>G-16</td>
</tr>
<tr>
<td>Management and Operating Contractor Selection</td>
<td>G-17</td>
</tr>
<tr>
<td>VI. DEMONSTRATION IMPLEMENTATION</td>
<td>G-18</td>
</tr>
<tr>
<td>Relations Between OSW and Stearns-Roger</td>
<td>G-18</td>
</tr>
<tr>
<td>Plant Operation</td>
<td>G-19</td>
</tr>
<tr>
<td>Development Program</td>
<td>G-21</td>
</tr>
<tr>
<td>Private Sector Involvement</td>
<td>G-22</td>
</tr>
<tr>
<td>VII. OUTCOME</td>
<td>G-25</td>
</tr>
<tr>
<td>Effect of the Demonstration Program on OSW</td>
<td>G-25</td>
</tr>
<tr>
<td>Effect of the Demonstration Plant on Other Elements of the Program</td>
<td>G-26</td>
</tr>
<tr>
<td>Technical-Economic Accomplishments</td>
<td>G-26</td>
</tr>
<tr>
<td>Institutional Accomplishments</td>
<td>G-27</td>
</tr>
<tr>
<td>Effect of the Demonstration on Potential Users</td>
<td>G-28</td>
</tr>
<tr>
<td>Effect of the Demonstration on the Private Sector</td>
<td>G-29</td>
</tr>
</tbody>
</table>
VIII. DIFFUSION ................................................................. G-30
    Modes of Dissemination .............................................. G-30
    The Desalting Industry ................................................ G-31
    Adoption ......................................................................... G-32
    Obstacles to Diffusion .................................................. G-32
    Spinoffs .......................................................................... G-33

IX. AFTERMATH ...................................................................... G-34

X. CONCLUSIONS .................................................................... G-36

Appendix
   PUBLIC LAW 85-883 ......................................................... G-41

BIBLIOGRAPHY ..................................................................... G-45
I. INTRODUCTION

This is a case study of the saline water conversion demonstration plant in Freeport, Texas. It was built for the Office of Saline Water, Department of the Interior, as the first in a program of five such plants. Large scale conversion of saline water to fresh water had been heralded as the way to ultimately convert deserts into farmlands, but the economics of the process have prevented such projects so far. This study examines what information and experience were produced by the project and how they were developed.

This is one of a series of case studies chosen for the initial phase of Rand's analysis of federally funded technology demonstrations being conducted for the Department of Commerce.
The Office of Saline Water (OSW) in the Department of the Interior was formed in response to the Saline Water Act of 1952 (Public Law 82-448). It began with a modest budget of $175,000 for its first year, 1953. The budget grew steadily to $725,000 in 1958, the year in which the demonstration plants program was authorized. Until the demonstration program, OSW had emphasized research and development activity. It has even been suggested that the processes that were demonstrated would have been kept in the laboratory development phase for years if Congress had not mandated the demonstrations, which suggests that at least some of the processes were not ready for implementation on the scale of a demonstration plant.

LEGISLATIVE HISTORY

Interest in a potential water problem for the United States led to the introduction of legislation in the late 1940s on saline water conversion research, but none got out of committee. In 1950, President Truman recommended saline water conversion research in his budget message. More bills were introduced, but the first one enacted into law was the Saline Water Act of 1952 introduced by Representative Clair Engel of California.

The Saline Water Act authorized $2 million for a five-year program to develop practical, low-cost means of producing water for beneficial consumptive purposes from saline waters. This program was to determine the feasibility of the development of such production and distribution on a large-scale basis. Under the provisions of the Act, the role of the Office of Saline Water was to develop new or improved conversion processes through research grants and contracts, to conduct research and technical development, and to fund engineering studies on lower investment and operating costs. The law was amended in 1955 to increase the authorization described above to $10 million and to extend the program through June 30, 1963.
DEMONSTRATION AUTHORIZATION

The demonstration program resulted from Congressional initiative. Senator Clinton Anderson, Chairman of the Senate Committee on Interior and Insular Affairs, was interested in desalination because of his state's limited water resources. The other members of Anderson's committee were also from potentially water-short Western states. Evidently, Anderson considered saline water conversion to be a promising technology, and his interest in promoting the testing of technology in the field led to his sponsoring of the Demonstration Plant Act of 1958.\footnote{Among Senator Anderson's other accomplishments, he helped promote the Shippingport nuclear reactor demonstration. A quotation from Senator Anderson is engraved on the cornerstone of the Wrightsville Beach test facility. It says, "Experimentation is the Mother of Progress."}

Originally Congress was interested in the construction of one 10 million gallon per day (gpd) plant, but OSW objected, citing several technologies in need of applied research.

Senator Anderson introduced a bill calling for two demonstration plants for brackish water (one in the arid Southwest, one in the Northern Great Plains) and three plants for sea water (one on the Atlantic coast, one on the Pacific coast, and one on the Virgin Islands, a U.S. territory). The bill was not making much progress, and Senator Anderson complained to then Senate Majority Leader, Lyndon B. Johnson, that his bill could not get our of committee. Senator Johnson explained to Senator Anderson that the United States also had a Gulf Coast. After the Virgin Islands were dropped and the Gulf Coast added,\footnote{2The Gulf Coast was also a water-short area, and, therefore, it was as appropriate a region for such a plant as any of the continental United States sites.} Congress enacted a Joint Resolution. This bill was called the Demonstration Plants Act of 1958, Public Law 85-883 (dated September 2, 1958). It provided $10 million for the construction of at least these five plants, with minimum sizes established for three plants and a different process to be used in each plant.

ORGANIZATIONAL RELATIONS

Apparently, OSW had established relationships with some of the potential manufacturers of desalting equipment. Cooperative funding with General Electric in the early stages of saline water conversion work has
been mentioned. Most other potential designers' and manufacturers' relations with OSW appear to have been contract work for OSW. The major obstacle to greater investment by firms that might have profited from desalting technology was that although there was a potential market, there was no immediate market for the good. This lack of a market and sales meant that investment funds would have been diverted from other, on-going ventures. Before the demonstration program, OSW had had little contact with municipalities that might want desalting facilities. OSW was Interior's major organization in the saline water conversion effort, with some other of its agencies, such as the Bureau of Reclamation, doing some cooperative related research.

Through 1958, a little less than $3 million had been spent on saline water conversion R&D, and the demonstration authorization provided $10 million to demonstrate what had been learned. This required a major re-orientation of OSW in terms of administering construction and operating contracts instead of research and development contracts.

An understanding of the political and organizational context in which the saline water conversion demonstration plants program began is not sufficient background for examining the Freeport demonstration. The next section is a brief discussion of desalting technology and, in particular, of the process chosen for the demonstration plant at Freeport, Texas.
III. TECHNOLOGICAL BACKGROUND

OSW had sponsored research on many potential processes for saline water conversion in its first six years. The process used most frequently around the world and in marine applications at the time the demonstration program began was the submerged tube process. The potential processes are listed in Table 1.

PROCESS SELECTION

The process to be used in the first demonstration project was selected before the plant site was chosen. Secretary of the Interior Fred A. Seaton selected the process after studying the recommendations of a special three-man process selection board appointed by Fred G. Aandahl, the Assistant Secretary for Water and Power.

The 17 potential processes were evaluated by the selection committee. The Department of Interior criteria for selecting the first process follow:

1. The processes were to be selected on the basis of general process principles and not by designation of a particular manufacturer or vendor.

2. The plant was to be capable of producing fresh water suitable for one or more of the purposes specified in the law and with the minimum capacities for three plants as provided in the law.

3. The processes were to be in an advanced stage of development, as determined either by their having been used in production plants, or in successful medium size pilot plant operations sufficient to assure that there would be a minimum of problems that would cause long shutdowns.

4. As the cost of product water was of primary importance, processes or combinations having lowest total production costs
Table 1
CONVERSION PROCESSES CONSIDERED FOR DEMONSTRATION PLANTS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple-effect evaporation</td>
<td>2. Flash evaporation</td>
</tr>
<tr>
<td></td>
<td>a. submerged tube</td>
</tr>
<tr>
<td></td>
<td>b. long-tube vertical</td>
</tr>
<tr>
<td>3. Electrodialysis</td>
<td>4. Freezing</td>
</tr>
<tr>
<td></td>
<td>a. tortuous path flow</td>
</tr>
<tr>
<td></td>
<td>b. sheet flow</td>
</tr>
<tr>
<td>5. Vapor compression</td>
<td>6. Critical pressure</td>
</tr>
<tr>
<td></td>
<td>a. rotary</td>
</tr>
<tr>
<td></td>
<td>b. tubular</td>
</tr>
<tr>
<td>11. Ion-exchange</td>
<td>12. Others</td>
</tr>
<tr>
<td>13. Combinations of the above</td>
<td></td>
</tr>
</tbody>
</table>

were to be given preference, and the processes selected had to have good potential for producing water at lower total cost than existing commercial plants, if any, utilizing the same general process principles. Some preference was to be given to processes that offered promise of significant further economies if built in considerably larger sizes, or through additional future improvements, or both.

5. The processes selected had to be such that the plants built would have all of the necessary features to qualify as a "demonstration plant" as that term was defined in Sec. 1(c) of Public Law 85-883, as follows:

(c) As used in this joint resolution, the term "demonstration plant" means a plant of sufficient size and capacity to establish on a day-to-day operating basis the optimum attainable reliability, engineering, operating, and economic potential of the particular sea water conversion process or the brackish water treatment process selected by the Secretary of the Interior for utilization in such plant.

6. The process had to be potentially adaptable to ultimate extensive use in appropriate areas of the Continental United States.

7. The process had to have a "look to the future" with respect to energy, materials, and changing conditions.

8. Both those processes that had been developed directly through the Saline Water Program and those that had been developed independently had to be given full consideration.

According to one of the selection committee members, the evaporation processes were judged to be the best developed processes and their use in other industries was interpreted as having proven commercial feasibility. The long vertical tube process was deemed the most promising of the evaporation processes.

Although the long vertical tube evaporation (VTE)\(^1\) process had been implemented only in a fairly small, 2,000 gallon per day (gpd)

\(^1\)This process is also called the long-tube vertical (LTV) process.
pilot plant at Wrightsville Beach, North Carolina in operation since November 1957, the process had been used commercially in the pulp industry to concentrate liquids such as waste sulfide. The VTE process was recommended for use in the first demonstration plant on the basis of its potential for superior performance, and its selection by Secretary Seaton was announced on March 2, 1959. While the committee perceived that it was following the criteria, the demonstration later showed that the use of the process in other industries did not provide the information necessary for the scale-up from the small pilot plant to a one million gallon per day operation. This process is illustrated in Figure 1.

![Diagram of the VTE process]

**Fig. 1--Vertical tube distillation process**


The same selection committee recommended all five processes, one for each of the demonstration plants in the program.

**THE VTE PROCESS**

The development of the long VTE process for saline water conversion began in 1955. OSW contracted with W. L. Badger and Associates, a consulting engineering firm in Ann Arbor, Michigan, to study the potential advantages of multimillion gallon per day distillation cycles.
Badger proposed the use of long-tube vertical (LTV) evaporators, common to the salt and chemical industry. As a result of that work, OSW concluded the process was very promising if scaling and corrosion could be prevented at little additional cost. Following the study, OSW sponsored W. L. Badger and Associates to explore methods of cost reduction before construction of a full-scale demonstration. This led to the establishment of an experimental facility at Harbor Island (Wrightsville Beach), North Carolina that used a single seven-tube LTV evaporator to simulate a large, multiple-effect distillation cycle.

Several organizations cooperated with OSW and W. L. Badger and Associates in the pilot plant project. Anticipating the potential for a new market, the Whiting Corporation (Swenson Evaporator Division) of Harvey, Illinois, provided the test evaporator at no cost. The International Nickel Company and the U.S. Navy Bureau of Ships, which was interested in a more efficient desalting process for its ships, provided land and facilities at no cost to OSW. It is not clear whether W. L. Badger and Associates provided any free services or whether they were paid for all their work.

The LTV process pilot plant was operated almost continuously from its start-up in November 1957 to the time that the VTE demonstration was designed. This experience was thought to have provided information on the actual operating conditions that would be encountered by the one million gallon per day (mgd) plant for Freeport. It turned out that, as most engineers would have expected, there were serious scale-up difficulties when the demonstration plant was built. These difficulties are described in the section on the operation of the demonstration.
IV. FEDERAL GOALS

Each of the major federal actors in the development of this program had markedly different ideas about what the demonstrations could and should accomplish. This divergence of goals probably played an important part in the lack of any well-defined target audience, because the definition of such an audience would have implied the dominant goals for the program.

THE CONGRESS

The Congressional goals for the demonstration program were stated in the Demonstration Plants Act of 1958. The plants were "designed to demonstrate the reliability, engineering, operating, and economic potentials of the sea or brackish water conversion processes,"¹ which the Secretary of the Interior was to select from among "the most promising of the presently known processes." Congress emphasized domestic applications of the techniques chosen.

THE PRESIDENT

President Kennedy, in his telephone address to the Freeport dedication ceremony, placed emphasis on the international aspects of desalination. He said, "I am hopeful that the United States will continue to exert great leadership in this field and I want to assure the people of the world that we will make all information that we have available to all people."² Presidential interest in the use of desalination technology in foreign policy continued with President Johnson. President Johnson announced a "Water for Peace" program during activities connected with the First International Symposium on Water Desalination, which was held in Washington, D.C. during October 1965.³ This objective of international leadership was vaguely defined, and not targeted at any specific region of the world.

¹See Appendix B for Public Law 85-883.
²Text of President's remarks in OSW Annual Report, 1961, p. 79.
THE OFFICE OF SALINE WATER

The Department of the Interior (DOI) and OSW had another understanding of the goals of the demonstration plants program based on a more solid understanding of the technical issues involved. While aware of the potential for international leadership with desalting technology, DOI's goals emphasized a demonstration of the reliability of available techniques and evaluation of the potential of improved versions of these processes without suggesting a demonstration of economic feasibility. Early in the program, Secretary Udall wrote:

While these five plants will demonstrate the feasibility and reliability of the selected processes, together with needed and useful engineering and operating data, they cannot be expected to demonstrate the economic potential of the various projects . . . To verify the economic potentials of the processes presently being demonstrated, plants ranging in size from 5 to 25 million gallons per day capacity will be required.¹

Recognizing the conflicts inherent in the legislative objectives and the impossibility of economic competitiveness, OSW approached the development of tradeoffs of the stated realizable goals at the expense of cost. OSW's 1961 Annual Report mentioned, "It is not possible, however, to design an optimum plant that demonstrates reliability and experimental flexibility, and that also produces the lowest cost water." The three key adjectives of the compromises necessary with respect to the objectives for the plants were: economical, large, and experimental. For Freeport (and probably for the other plants as well), OSW appears to have interpreted the Congressional purpose as being more development-oriented than as demonstrating the actual commercial feasibility of a saline water conversion plant. This idea was held by Secretary of the Interior Seaton as well, who announced, "This new law will substantially accelerate the rate of development of new processes the Department has under research."²

¹Letter from Secretary Stewart Udall to President John F. Kennedy in OSW Annual Report, 1961, p. v.
While Congress seems to have viewed the demonstration plants as an effort to disseminate OSW's research and development work, OSW viewed them as part of its R&D efforts. In fact, OSW published the demonstration plants' annual reports in its "Research and Development Progress Reports" series. Most of OSW's work had been technical in nature, and so the demonstrations were treated similarly. The President's emphasis of a third perspective, the international policy uses of desalting, gradually influenced OSW's view of the program.

OTHER DOI AGENCIES

The Department of Interior had strong interests in water conservation and development, and it had many bureaus and offices in addition to OSW that were addressing the water problem. They included the Bureau of Reclamation, the Bureau of Land Management, the Bureau of Indian Affairs, the Geological Survey, the Bureau of Mines, the Office of Water Resources Research, and the Federal Water Pollution Control Administration. The demonstration plants program greatly increased OSW's budget and probably improved its stature relative to the older agencies.

INDUSTRY

This program was agreeable to some potential private suppliers. The private sector was interested in exploring the market potential for desalination. There was no sustained interest\footnote{G.E. was involved in a 50-50 agreement with OSW in the predemonstration period, but they never made a serious commitment to desalination and finally dropped out.} in cost-sharing arrangements between the government and potential manufacturers because there was no existing market for desalting technology. As mentioned earlier, manufacturers did make some in-kind contributions to OSW's work. However, some firms, such as Westinghouse, avoided working with OSW on desalting technology when possible because all information and patents developed were considered to be public property. This would have hindered Westinghouse's ability to gain a competitive advantage through involvement in the early stages of the technology's development. OSW also seemed to be more interested in investigating novel desalting concepts.
than the somewhat conservative private sector might have preferred. OSW's interest in private sector involvement emphasized its research and construction and operation of its demonstration plants, and so it did not encourage private industry to take over the improvement and promotion of desalination.

TARGET AUDIENCE

There is no evidence of a conscious decision to aim the demonstrations at a particular audience. As mentioned earlier, the White House was concerned with desalination's effect in the international arena. Congress had mentioned domestic use, but there was no outcry about the international attention given to the program. OSW appears to have been interested in promoting the technology at home and abroad.

The economic goal set for the Freeport plant was to produce 1 million gallons per day of fresh water for municipal and industrial use for between $1.00 and $1.25 per thousand gallons.

The next section describes the process through which Freeport was selected for the demonstration program and the initial activity to provide the demonstration plant.
V. INITIATION AND SELECTION

DESIGN CONTRACTOR

Because W. L. Badger and Associates had done the early design work for OSW on the long vertical tube evaporator process and had worked on the pilot plant, OSW awarded them the contract to do the preliminary design for the demonstration. In close cooperation with OSW's technical staff, Badger and Associates established general process conditions for the plant, including major equipment, and work. The work comprised a flow sheet, functional drawing preparation, and an outline of the operational program for the process. The cost reimbursable negotiated design contract with a limit of $50,000 on expenses was approved in March 1959.\(^1\) It was followed in September by a $62,000 contract to the Badger firm for the demonstration plant's architectural and engineering services.\(^2\)

SITE SELECTION

The particular site within each of the geographic regions specified by Congress was selected by the Secretary of the Interior. Secretary Seaton appointed a three-man committee to select the sites for five plants. The members of this committee were all engineers, an engineering professor, a consultant, and the president of the American Water Works Association.\(^3\)

The selection of the long tube vertical distillation process for the first plant meant that the first demonstration had to be one of the coastal sites. Sea water has a much higher salt concentration than does brackish water, and, therefore, different processes are appropriate for desalting the different waters. The first process chosen was best applied to sea water conversion.

\(^1\)DOI Press Release, March 20, 1959.
\(^3\)DOI Press Release, April 23, 1959.
In November 1958, the Department of the Interior announced it was seeking state and local cooperation in the site selection.\footnote{DOI Press Release, November 3, 1958.} Over 200 communities requested and responded to a prospectus, "General Guides for Saline Water Plant Location Considerations," including 31 Gulf Coast sites.\footnote{DOI Press Release, June 19, 1959.} Interior also promoted state and local financial assistance for the projects. The Gulf Coast was chosen for the first plant, but it is not clear how this choice was made.

Some of the sites volunteered were eliminated because they failed to meet the following criteria:

1. There was no need for additional water because existing supplies were adequate.
2. Water consumption and the existing water supply system were too small to use the amount of water that would be produced by the conversion plant.
3. The saline water source was seriously contaminated.
4. There were no means for disposal of brine without complicated and costly facilities.
5. Hazardous design and operation would have been imposed by environmental, topographical, and meteorological conditions.
6. The cost to reach water was prohibitive.
7. The site did not meet Public Law 85-883 requirements.\footnote{DOI Press Release, June 17, 1959.}

Proposed sites not eliminated by the above criteria were officially evaluated by a rating system that compared technical factors (62 percent), demonstration value (24 percent), and assistance offered (14 percent). The significance of this formula in the actual decisionmaking process is not known.

After the Gulf Coast was chosen for the first plant, seven Gulf Coast cities were selected for visits by the selection committee. They were Key West, Florida; Gulfport, Mississippi; Rockport, Freeport,
Corpus Christi, Port Isabel, and Brownsville, Texas.

The Freeport Chamber of Commerce was interested in getting one of the demonstration plants, and the Dow Chemical Company's aid was enlisted. Freeport is the site of one of the largest chemical complexes in the world, so Dow was an important ally. Dow's interest in the project included civic concerns as well as getting necessary water. Dow offered to donate about five acres of land, to sell electricity and process steam to the desalting facility, and to buy half the product water at 30 cents per thousand gallons (a fairly high price). The sale of steam and electricity meant that the demonstration plant would not have to build its own support facilities to supply these energy sources. Freeport offered to buy half the product water at 20 cents per thousand gallons and to contribute $10,000 toward the construction of the connection of the plant's output to the city water system.

Secretary Seaton announced the selection of the Freeport site at the National Convention of the American Water Works Association (AWWA) in July 1959. Freeport was selected because it offered "several features not available at other locations."¹

CONSTRUCTION CONTRACTOR SELECTION

In March 1960, construction bids were sought for a turnkey contract, with primary responsibility held by a single contractor. Four bids were received, and the lowest bidder, Chicago Bridge and Iron Company, was awarded a $1,245,250 contract. The unsuccessful companies were: Rust Engineering Company, Birmingham, Alabama ($1.3 million); Hensszy Company, Inc., Watertown, Wisconsin ($1.5 million); and Tellepsen Petro-Chemical Construction Corporation, Houston, Texas ($1.5 million).²

MANAGEMENT AND OPERATING CONTRACTOR SELECTION

In January 1961, a management and operating contractor for Freeport was sought. This contract was to be awarded on a negotiated basis with an operating contractor who possessed the "necessary scientific, technical, engineering and operating staffs and skills to operate this type of plant." In addition to management and operation of the plant, the contractor had to prepare regular operating cost reports and engineering reports on phases of the work that would promote more economic operation of the plants. The Stearns-Roger Manufacturing Company of Denver, Colorado, and Houston, Texas, was selected for this task. The contract called for payment of cost plus a fixed fee (CPFF). ¹

VI. DEMONSTRATION IMPLEMENTATION

Despite bad weather, the plant was finished close to the completion date. The cost overrun was only $10,000 on this $1.2 million contract. The contract was a standard construction contract involving progress payments as work was completed.

The performance of the operation and management (O&M) contractor, Stearns-Roger Manufacturing Company, was considered satisfactory. There were greater overruns in the cost estimates for the O&M contract than for construction. These increases were estimated at 20 to 25 percent. This estimate exaggerates the overruns because expenses for extraordinary occurrences (such as Hurricane Carla) were considered as overruns. The CPFF contract appears to have played an important role in the Freeport plant's O&M. One point mentioned was that the CPFF arrangement meant that Stearns-Roger did not necessarily share OSW's incentive to run the facility at least cost in order to demonstrate the most economical operation of the VTE process with the state of the art available at the time. However, a CPFF contract was considered necessary because the great uncertainties involved with the Freeport plant made it infeasible for anyone to make a reasonable a priori cost estimate. No incentives for lower cost operation were included in the contractual arrangements because incentive contracting was not in Interior's contracting procedures at the time.

RELATIONS BETWEEN OSW AND STEARNS-ROGER

OSW maintained contact with Stearns-Roger through a field engineer at the site and with technical support from its Washington, D.C. offices. As far as site operation and management activities were concerned, the site engineer was autonomous; but when plant modifications that would change the process were considered, OSW in Washington was consulted; and the staff had to concur with the modifications. Some plant modifications were initiated by OSW's Washington technical staff. Under normal circumstances OSW held quarterly meetings with Stearns-Roger to
discuss problems and progress, but there were frequent communications by telephone.

The communication between Stearns-Roger and OSW kept OSW informed and allowed Stearns-Roger to get counsel from the OSW technical support. Apparently, the OSW, Washington, and Stearns-Roger, Freeport contact developed a momentum of its own, and the direct communication may have gotten excessive. Stearns-Roger engineers often got in touch with the Washington support directly, without either party informing Mr. Singleton, the resident engineer. In some instances, this was described as leading to Singleton's not knowing precisely what was being changed in Freeport. That is, modifications were approved by Washington with Stearns-Roger but Singleton was not made aware of these modifications at the time. Charles Crua, the person who became the resident engineer at Freeport shortly after the plant's change to a test bed, revised this practice and insisted that all communication be through him.

**PLANT OPERATION**

In September 1961, Freeport was hit by Hurricane Carla. The plant was flooded with six feet of sea water, which caused considerable damage to pumps, motors, and electrical switch gear. However, the saline water conversion process equipment suffered only minor damage. After four days of around-the-clock work following the receding of tidal flood waters, the plant was again producing potable water. DOI understood that this emergency action was taken in anticipation of a critical water shortage in the disaster area, but most of the water produced was sent to Dow, with "a small amount...pumped through the Freeport city mains for flushing." 

The operation of the Freeport demonstration from mid-1961 to late 1963 was evaluated by Stearns-Roger to have produced extensive and valuable operational and maintenance experience. During this early period most of the problems encountered were attributed to the engineering

---


difficulties of scaling up to a 1 mgd plant from a 2,000 gpd pilot plant operation. The scale-up problems were related to such changes as the different fluid dynamics involved with the greater capacity. Another scale-up problem was related to the different location of the demonstration and pilot plants as much as to the different sizes. The significantly greater turbidity of the sea water available at Freeport apparently was unnoticed in the screening of the potential sites, but it turned out to create a problem by preventing the effectiveness of the measures developed to prevent deposits from forming in the distillation equipment. While these problems were not process problems, they affected the performance of the process.

The third annual report on Freeport summarizes the notable achievements of this period:

- Identification of realistic operating limits as originally conceived.
- Successful, if not economical and completely understood, operation of the pH method of decarbonation and vacuum deaeration.
- Elimination of scale formation in effect I.
- Installation of tubing material which not only resists corrosion but also improves heat transfer.
- Incorporation of recycling systems for the low-temperature effects resulting in better heat transfer and considerable reduction in scale formation rate.
- Elimination of six condensate-to-feed exchangers with negligible loss in economy (2500 SQ-FT of heat transfer surface).
- Many changes to redistribute pumping capacity and improve the reliability of pumping equipment.¹

In December 1963 and January 1964, Stearns-Roger evaluated the investigative program that had been in effect and recommended a long-range development program for the Freeport facility. This program was "to develop and improve the design, performance, and costs of this promising LTV process plant" (emphasis added). The process variables were judged to be under sufficient control that cause and effect relationships could be identified. The major problems addressed by these development runs were the fouling of equipment by scale formation and silt accumulation, corrosion and erosion problems, and water production costs.

Stearns-Roger recognized the development dilemma when they said:

"Full realization of the potential thermal advantages of the LTV will significantly reduce the cost of water produced by this process. It is necessary, therefore, to pursue the problems which limit operation, in a manner which does not yield the lowest immediate costs."

Nevertheless, OSW approved the development program. Evidently, the promise of significantly reduced costs through larger plants and the need for larger plants to make any noticeable impact on the world's water supply picture were sufficient reasons for OSW to let more development activity be pursued at Freeport in spite of the plant's demonstration goals.

DEVELOPMENT PROGRAM

The development program was concerned with the testing of operating methods, equipment changes, and the correlation of performance data. The phases of the process emphasized were:

- Deaeration and Decarbonation
- Feed Pretreatment
- Feed Preheat and Product Condensation
- Concentration Ratio (Extraction Ratio)
- Brine Distribution and Scale Formation Control
- Product Water Conditioning
- Desuperheating Supply Steam

\[1\] Ibid., p. 74.
First Effect Operating Temperature

Materials of Construction (Corrosion and Erosion)¹

By the end of FY 1965, nine development runs had been completed at the Freeport facility.² Development Run Number 1 began on February 6, 1964, and ran until March 3, 1964.³ Each of the subsequent runs took between a few weeks and a few months and was followed by an evaluation period during which the plant was down. Some of these runs involved several parts each followed by a down period.⁴ This pattern of frequent down periods and the consequent failure of the Freeport facility to demonstrate the potential for reliable operation turned out to be significant in a way that probably was not expected. A major promoter of VTE technology, formerly with Chemico (an American firm whose process relies heavily on the Freeport experience), explained that potential customers for desalination facilities have tended to avoid the VTE process because Freeport's track record is interpreted as demonstrating unreliability rather than as being evidence of the systematic attempt to improve the process.

PRIVATE SECTOR INVOLVEMENT

There was no significant private sector involvement, other than the contractors and Dow, in the Freeport demonstration. There were some testing facilities built in Freeport by industrial organizations, such as the American Iron and Steel Institute and the Copper Institute. These facilities tested materials for use in desalting plants. However, this activity did not occur until after the Freeport plant was converted to a test bed.

Dow was interested enough in the Freeport work to propose a novel design of a vertical tube evaporator process involving a concentric

¹Ibid., p. 75.
design for the process effects (chambers). This interest appears to have been related to the existence of a Dow contractual research division. Although Dow was interested in the market potential for desalting and has since become involved in reverse osmosis desalination, the concentric effects idea was not funded by Dow. Instead, the research division proposed the concept to OSW for funding (which never materialized).

At some point during the demonstration, both purchasers of Freeport's product water decided they wanted to curtail the buying arrangement. Rainfall returned to normal levels after a severe drought. The expenditures for the 20 cents per thousand gallons being paid by the Freeport municipal water system was judged to be consuming too large a share of the system's water budget. The reasons for Dow's withdrawal are not as clear. One explanation given is that the Freeport plant's frequent shutdowns made it an unreliable source of water and that the unreliability and high cost brought Dow to opt out of the project. Another explanation is that Dow would have continued purchasing the water except that when a higher pressure boiler was installed at Dow, purer water with almost no dissolved solids was required and that the demonstration project's management decided to end the agreement rather than try to meet the new standards. After ending the agreement, Dow got water from a nearby river and treated it itself. The second explanation is somewhat confusing in light of OSW's subsequent action with the municipal water system. OSW was especially interested in continuing to feed water to the municipal system because of an interest in developing a treatment that would make the product water compatible with existing municipal water distribution systems. The ion-less plant output was "hungry water" that "ate up" the deposits that developed on the pipes over time. The introduction of this distilled product water had caused water to come out red in homes.

It was estimated that Freeport paid approximately 3 cents per thousand gallons for its other water, mainly for the pumping of ground water, and OSW agreed to sell product water for 3 cents per thousand

---

1>This description of the product water as ion-less suggests a high degree of purity (the unattainable goal mentioned in the second explanation of Dow's withdrawal).
gallons. This allowed work on output water treatment to continue. Since OSW became interested in showing compatibility with municipal uses, one would expect there would have been similar interest in showing compatibility with the industrial use.

The original authorization for the demonstrations was for a seven year program. When this authorization was extended, OSW was allowed to convert the demonstration plants to test beds. With this change, OSW was better able to continue the engineering development work it desired to do, without the constraints imposed on the plant when the primary objective was to be a demonstration.
VII. OUTCOME

EFFECT OF THE DEMONSTRATION PROGRAM ON OSW

The passage of the Demonstration Plants Act of 1958 (Public Law 85-883) shifted the orientation of OSW from research activity toward the demonstrations. The last Director of OSW (Mr. Pat O'Meara) described the demonstration plants program as "using $10 million to demonstrate $3 million of research." The impact of the demonstration program in terms of the OSW budget appropriated can be seen from the presentation of the budget over time in Table 2.

Table 2
OSW FUNDING, OVER TIME

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Program Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>$175,000</td>
</tr>
<tr>
<td>1954</td>
<td>400,000</td>
</tr>
<tr>
<td>1955</td>
<td>400,000</td>
</tr>
<tr>
<td>1956</td>
<td>600,000</td>
</tr>
<tr>
<td>1957</td>
<td>550,000</td>
</tr>
<tr>
<td>1958a</td>
<td>725,000</td>
</tr>
<tr>
<td>1959</td>
<td>1,183,000</td>
</tr>
<tr>
<td>1960</td>
<td>3,605,000</td>
</tr>
<tr>
<td>1961</td>
<td>3,795,000</td>
</tr>
<tr>
<td>1962</td>
<td>9,805,000</td>
</tr>
<tr>
<td>1963</td>
<td>9,785,000</td>
</tr>
<tr>
<td>1964</td>
<td>11,850,000</td>
</tr>
<tr>
<td>1965</td>
<td>16,150,000</td>
</tr>
<tr>
<td>1966</td>
<td>22,485,000</td>
</tr>
<tr>
<td>1967</td>
<td>29,815,000</td>
</tr>
<tr>
<td>post-1967</td>
<td>111,309,000</td>
</tr>
</tbody>
</table>

"Demonstration program authorized.

In 1961, the demonstration plant activity was handled by a division, with Allen Cywin as chief. At that time, the division's work was done by the chief, two senior engineers at headquarters, and field engineers (one at each site). In 1962, Raymond H. Jebens became chief of the

\[1\] OSW Annual Report (1961), p. 76.
division; the division's major activity for that year involved four of the five demonstration plants. In 1963, the division's activities expanded to performing engineering studies on the feasibility of desalination in the Florida Keys, the Pacific Southwest, and arid areas in some foreign countries in addition to the demonstration plant effort.

1964 was viewed as a turning point for Interior's approach toward saline water conversion. This change involved a shift from laying a solid and broad foundation for desalting technology and demonstrating the applicability of various processes toward "more intense engineering development of those specific processes best adapted to satisfying identifiable water needs." It appears that the demonstration plants had a major influence in this shift, even though the shift lagged Public Law 85-833 by several years. About the same time, recommendations were made to reorganize OSW.

In early 1965, OSW was reorganized, and an Engineering Services Division headed by Jebens handled the demonstration program. This division reported to an Assistant Director for Engineering and Development (Jack Hunter). Another assistant director was in charge of research (W. Sherman Gillam).

EFFECT OF THE DEMONSTRATION PLANT ON OTHER ELEMENTS OF THE PROGRAM

The Freeport, Texas demonstration plant was the first of the five plants constructed. The construction of the other plants began shortly after the Freeport work, and, therefore, no special effort was made to apply lessons from the experience with the first demonstration to the other demonstrations.

TECHNICAL-ECONOMIC ACCOMPLISHMENTS

Although there were technical difficulties with the Freeport plant (Demonstration Plant No. 1), it seems to have been a showpiece of the

---

2 OSW Annual Report (1963), pp. 143-144.
demonstration plant program. There were several visits by diplomats and foreign technical teams to the Freeport facility. OSW became an international clearinghouse for desalting information, but the influence of the demonstration plants in this development has not been established.

The extension of the plant authorization for more intense development activity was requested by OSW because the demonstrative nature of the plants generated fairly severe constraints on the development work possible. The perceived success of a demonstration plays an important role in its effects on potential adopters and users. This success has technical, economic, and institutional elements.

The principles involved in the production of fresh water from saline water at Freeport are fairly straightforward. The technical problem was never how to desalt saline water, but how to produce fresh water from saline water cheaply. The Freeport plant was expected to produce fresh water for $1.00 to $1.25 per thousand gallons.\(^1\) By 1965, the normalized cost\(^2\) for production was $1.09 per thousand gallons, and so this goal was reached. At that time it was estimated that the cost could be reduced to about $0.81 per thousand gallons if the plant capacity was increased from its average of 1 mgd to 1.6 mgd.\(^3\)

Although the technical goal of production for $1.00 per thousand gallons of fresh water was achieved, this was not a feasible rate to charge for water in the United States. The effect on Freeport's municipal water system is evidence that even a price one-fifth of that attained by the Freeport demonstration would still have been excessive, even for a city such as Freeport, which was concerned about its water supply.

**INSTITUTIONAL ACCOMPLISHMENTS**

The demonstration encountered no major institutional obstacles to


\(^2\) The development and evaluation activity at Freeport was a significant part of the project's costs. The normalized cost was a device developed to estimate the cost of producing fresh water from the costs of the production activity alone.

providing desalted sea water for municipal use. One potential obstacle, health codes, was overcome without any real problem. The Texas State Department of Health Laboratories collected samples of water produced by the plant during initial runs and tested its bacteriological quality. No delivery of water into the city system was allowed before these tests were completed satisfactorily. The product water was found to be free of coliform organisms and to be of satisfactory bacteriological quality for municipal use. The only minor problem encountered was that the form used by Texas State officials did not have provision to cover the source of supply. Since the form listed only river, cistern, spring, reservoir, lake, and well, a special entry had to be made to indicate the Gulf of Mexico as the water source. Thus the plant helped show the institutional and technical feasibility of supplying fresh water from saline water, but for most cases (especially within the United States), the costs were still too great.

**EFFECT OF THE DEMONSTRATION ON POTENTIAL USERS**

The group that had to be influenced to affect the potential users, municipal water systems, was the community of municipal water engineers. The professional organization for these engineers is the American Water Works Association (AWWA). OSW had difficulty interesting the AWWA in desalination technology. OSW interpreted the lack of interest as an inability to understand the technology. The municipal water engineers perform relatively mundane tasks, their major concerns being the practical benefits of saline water conversion (one heavily involved engineer said, "The desalting business is a disease."). It is easy to understand the frustration of these persons working on the frontiers of knowledge when confronted with the indifference of the potential users. However, it is just as easy to see why American municipal water engineers, who have done such an outstanding job of providing water that most Americans take it for granted, would view desalination as a pie-in-the-sky idea. Basically, AWWA was cool to desalting because sufficient fresh water was available and the conversion processes were expensive. OSW finally got the AWWA interested in desalination and it formed a Committee on Desalting. Also, desalting exhibits and presentations became regular items at the annual national conventions. This turn-around was not
related directly to Freeport, but the demonstration plants program was involved.\footnote{This is described in greater detail in the discussion of diffusion in the next section.}

**EFFECT OF THE DEMONSTRATION ON THE PRIVATE SECTOR**

The potential suppliers of desalting equipment did not seem to have been especially interested in the Freeport plant. One of the major reasons appears to have been that since all patents and data developed were public property, a manufacturer could not gain any competitive advantage by getting involved. OSW did not consider the potential manufacturers of desalination equipment to be allies.

The Stearns-Roger Corporation tried to apply the know-how it gained at Freeport to build a VTE process plant at St. Croix in the Virgin Islands. The plant's heat transfer surface failed to meet production guarantees, and Stearns-Roger had to pay the Virgin Islands Water and Power Authority a substantial cash penalty. Rather than capitalize on their initial error, Stearns-Roger decided to drop out of the desalting business. Although the plant did not meet design capacity, it has operated reliably at a capacity of 900,000 gpd since its completion.\footnote{\textit{J. W. O'Meara}, private communication, Department of Interior, August 22, 1975.}

Stearns-Roger's Project Engineer for Freeport, David Kays, was convinced of the potential of the VTE process, and he left Stearns-Roger to continue promoting the VTE process at Envirogenics, a division of Aerojet Corporation. Mr. Kays' activity is discussed in the next section, which addresses the issue of the diffusion process of the technology developed at Freeport.
OSW was concerned about disseminating its information on saline water conversion and promoting desalination. In many cases, however, it is not possible to distinguish between promotion of the VTE process used at Freeport and promotion of desalting technology demonstrated by the program as a whole. The OSW efforts were directed at foreign and domestic audiences.

MODES OF DISSEMINATION

The devices used by OSW to publicize the demonstration projects and other desalination work included:

- Participation of President Kennedy and presence of Vice President Johnson and Secretary of Interior Udall at the dedication of the Freeport demonstration plant.
- Sponsorship of international symposia on desalination.
- Contracting with Atomic Industrial Forum, Inc. to organize an international industrial exhibit by commercial manufacturers of saline water conversion systems.
- Availability of patents to general public without royalties.
- Service as NATO's clearinghouse on desalination activity.
- Visits to Freeport by more than 30 foreign ambassadors and at least one head of state (Israel).
- Publication and distribution of annual reports on Freeport by the O&M contractor, Stearns-Roger.
- Reports on the demonstrations in professional society journals, including the American Institute of Chemical Engineers, the American Society of Mechanical Engineers, the National Association of Corrosion Engineers, the Instrumentation Society of America, and the American Water Works Association.
- Responses to more than 3,300 requests for information and data and to "countless telephone inquiries."
- Cooperation with the M. W. Kellogg Company of New York City in the publication of the Saline Water Conversion Engineering Data Book.
There appears to have been quite a bit of local interest in the Freeport project. Charles Grua, who became OSW's resident engineer after Harold Singleton joined Dow in Freeport, said he spoke on desalination to the local meeting of some professional society almost every week while he was in Freeport. He also spoke frequently for educational and civic organizations. He said that the Houston Post once had a special section on water problems with several pages devoted to desalination, but he could recall no such item in a national periodical.¹

OSW made a real effort to "bring (the AWWA) around." When the National Convention was held in San Diego, OSW provided buses at the convention center to take the engineers to the San Diego demonstration plant. As mentioned earlier, OSW's efforts were successful in gaining official recognition of desalination as a legitimate activity in which municipal water engineers could be engaged. The high point of the OSW-AWWA relationship probably was the publication in November 1972, of an issue of the AWWA journal devoted entirely to saline water conversion.² The present AWWA stance toward desalting appears to be that there is no great interest, but developments are being followed.

THE DESALTING INDUSTRY

At the time of the demonstration projects, there were about five major American companies involved in distillation desalination activity. Since then, some have dropped out, including Stearns-Roger, and some new entries have appeared. Others have been shifted from firm to firm. Today the industry still has a fairly low volume.

One of these firms, Chemico, relies heavily on the technology of the Freeport project, and one of the key people at Chemico was David Keys, the Stearns-Roger's Freeport project engineer. Chemico has built or is building seven saline water conversion plants worth about $30 million. These plants have been based on a combination process including the VTE process from Freeport.

¹I could find no relevant article listed in the Reader's Guide to Periodical Literature.
ADOPTION

The major market for desalting facilities has been outside the United States. The American manufacturers were competitive on the international market only for a brief period after the devaluation of the dollar. Although most foreign manufacturers have designed plants based on the use of their own technology, there recently has been foreign competition with the VTE-MSF process.\(^1\) It has been asserted that the Japanese have just verified earlier U.S. work (which presumably includes the VTE process demonstration at Freeport) and that the Germans have improved upon the U.S. work. British manufacturers have also taken advantage of the U.S. effort with VTE. Chemico has developed proprietary information on the VTE-MSF process, and evidently Aqua-Chem thinks that this information gives Chemico a significant competitive edge with respect to this process because it is developing another process.

OBSTACLES TO DIFFUSION

There appear to have been two obstacles to the diffusion of the desalination process used in Freeport. One was the high capital cost for constructing the plant. Although the VTE was thermodynamically more efficient than the MSF process, the initial building costs for the VTE process were significantly greater at the time of the demonstration plant program. When the development activity increased after Freeport's demonstration phase, a major reduction in construction costs was achieved through the development of a multi-effect VTE process with common wall construction. This made the VTE process more competitive financially. Later development led to the conclusion that a process combining the advantages of both the VTE and MSF would be superior to further development of either process independently.

\(^1\) The VTE-MSF process is a combination of the VTE process demonstrated in Freeport and the multi-stage flash (MSF) process demonstrated in San Diego.
The other obstacle faced by the VTE process was its novelty. There was a fair amount of desalination capacity in the world before the OSW demonstration plant program. This capacity was provided by the submerged tube process, which was an old and inefficient process. With the initiation of the OSW demonstration program, new construction of submerged tube plants was cut to near-zero. However, since the MSF process was further along in development than the VTE process at the time the demonstrations were authorized, the demonstration of the MSF process at San Diego, California went much more smoothly than the Freeport demonstration. This perceived superiority in reliability led to a preference for the MSF process by potential users of sea water conversion facilities. Evidently, potential foreign purchasers avoided the VTE process because it was (and still is) considered exotic. Thus they thought that major retraining of their desalting equipment engineers and operators would be required.¹ So, there was some diffusion of the VTE process concept, but most of it did not occur until after more engineering development had improved and modified the process.

SPINOFFS

There also was some spinoff of technology developed at Freeport. Special tubing was required for improving the transfer of heat from the input steam to distill the saline water. The original concept was brought to the attention of OSW by General Electric, and OSW contracted with the Oak Ridge National Laboratory to advance the design of enhanced tubes. Now the electric power generating industry is interested in the use of these tubes.

Desalination technology is being applied to waste water treatment to meet effluent discharge standards. A chromium plating plant experienced a net economic gain by recycling a concentrated chromium salt solution and the fresh water separated using desalination techniques. It is not clear whether the VTE or some other process was employed.

¹Significant retraining would not have been necessary.
IX. AFTERMATH

During the fall of 1974, the Office of Saline Water was discontinued and its duties were transferred to a new office, the Office of Water Research and Technology. The demise of OSW appears to be related to politics, but the official reason given is that private industry can now take over the necessary work on saline water conversion. Several industry representatives testified to the contrary before the Subcommittee on Water and Power Resources of the House Committee on Interior and Insular Affairs.¹ These industrial representatives stressed the important role of commercial scale demonstration plants in the sale of desalting plants and the inability (or unwillingness) of the private sector to make the capital outlays necessary for such demonstrations. Both proponents and opponents of the OSW budget cuts (from $26.8 million in FY 1973 to $2.5 million in FY 1974) agreed that the government should still fund the basic research in sea water conversion.

One explanation for the severe cuts is that OSW irritated OMB. When President Nixon was seeking a solution to the problem arising between the United States and Mexico over the salinity of the Colorado River, he appointed a committee chaired by Mr. Brownell to recommend a solution. OMB was strongly opposed to a solution requiring a large initial capital expenditure and significant operating expenditures. The committee included a "very persuasive" OSW person, and Brownell recommended a 100 mgd desalination facility. Six weeks later, OMB notified OSW of impoundment of funds and force reductions.

Another item suggested as an element in OSW's problems was its emphasis on the economic potentials of very large plants. In 1971 or 1972, Congress approved specific legislation calling for the design of plants for a large (40 mgd) desalination plant. OSW was not able to arrange a cooperative agreement with any locality, and the director, Mr. O'Meara, had to report to Congress a year later with no plan.

Since OSW's promotion of bigger plants had convinced Congress of their potential merits, their inability to take advantage of the opportunity supplied by Congress to build a larger plant led Congress to believe that OSW was not prepared for that job. The FY 1974 appropriation authorization hearings were very cordial, however, and there was no indication that the Congressmen were especially happy with the large cuts in OSW's budget. In any case, OSW's successes in some areas appear to have helped it put itself out of business.
X. CONCLUSIONS

The Freeport demonstration of the VTE desalination process resulted in improvement of the process and acceleration of its development largely because of the personal commitments of the involved professionals, but it did not lead to a wide diffusion of the process. The saline water conversion demonstration plants program as a whole appears to have been more successful in diffusing the innovation of desalination (rather than the innovation of the VTE process). Thus, the Freeport demonstration did not "fail" to promote adoption of the innovation it demonstrated, but it might be considered one of the relatively less productive elements of a program of technologically unproven processes. Such uneven results must be expected in a program with a fairly high degree of technological uncertainty.

The Congressional mandate of Public Law 85-883 required OSW to demonstrate some processes before they were ready for operation on a commercial scale. The VTE process was one such process. Since OSW's main interest had been research and development of desalination technology, the Congressional authorization was perceived not as an enforced side-tracking of its R&D effort but as an opportunity to accelerate process development in larger capacity plants.

OSW's work did promote U.S. leadership in desalting technology. Freeport played an important role in the presentation of desalination information to an interested international audience.

OSW appears to have done an effective job of disseminating the data generated at the Freeport project, but the information developed was not the information most appropriate for promoting adoption of the VTE process. The most desirable arrangement for the demonstration would have been the inclusion of potential adopters' inputs in its design. However, the need for the VTE and similar processes was so far down the road that no one perceived himself as a potential user. It probably would have been very difficult to get acceptance of an alternative where foreign potential users provided directions. However, the U.S. Virgin Islands might have provided the kind of concerned
feedback necessary to point out that continuous operation was more important to potential users at the time than was cutting production costs by some marginal amount.

There was no major incentive for OSW to produce water at the absolute minimum cost possible for the Freeport plant's capacity because Interior had already publicly asserted that the optimum size for the VTE process was at least an order of magnitude larger. The residual incentive OSW might have had to produce fresh water at a minimum cost was negated by the cost-plus-fixed-fee contract under which the O&M contractor worked. The technical uncertainty had made the CPFF contract necessary, and this, in turn, let Stearns-Roger encourage OSW's tendency to pursue process development instead of a reliability demonstration.

A fundamental question is whether it was appropriate for the federal government to fund the Freeport demonstration. Since lack of an identified market was a major reason for little private sector initiative on desalting, perhaps OSW should have tried to help define and identify the market instead of demonstrating desalting techniques. In that way, the technology would have been demonstrated by private firms. Because of the economics of the VTE process, establishment of such communication would have been difficult domestically. The lack of venture capital to build demonstrations indicates that federal involvement probably would have been necessary anyway. Not enough information has been developed to provide a definite answer about whether promotion of this innovation had sufficient public benefit to justify federal support.

Another important question is whether a demonstration plant was an appropriate means of promoting the VTE desalination process in particular. There are strong indications that the demonstration played a very important part in the diffusion process for desalination in general by decreasing the uncertainty connected with the potential sources of a vital good, fresh water, and that it could have promoted the VTE process if the plant were run differently.

This can be understood more clearly if one considers the supply and demand curves for an individual, as illustrated in Figure 2. Demand
would be close to perfectly inelastic for the amount of water needed to survive. If water could be supplied by any of the three supplies in Figure 2, a purchase at an equilibrium point would yield a large consumer surplus in each case. Given the abundant supply ($S_{US}$) is not available, the difference in the price for supply by VTE or MSF is minor compared with the value of the water to the consumer. In such a situation, the consumer is likely to choose the source he perceives as more certain. This happened with the VTE process. The San Diego demonstration of the MSF process went very smoothly and the Freeport demonstration of the VTE process was down frequently. Even though the VTE process was more efficient and could have been operated steadily if constant attempts at process improvement were suspended, it often was not even considered as a possibility for a new desalting facility because the countries willing to pay the price to desalt water were willing to pay a marginal increase for the certainty of MSF-based processes. This rejection phenomenon seems to have been extended to the significantly cheaper VTE-MSF combination process because no large scale demonstration has been operated.¹

¹Figure 2 also illustrates why there has been little domestic diffusion of any of the distillation processes. There still is cheaper water available in the coastal regions where such processes would be appropriate.
Although OSW appears to have been successful in promoting desalination, the emphasis on development at Freeport hindered its acceptance in the short run but improved the potential of the process.

In summary, the factors contributing to the accomplishments of the Freeport demonstration plant included:

- Interest in desalination of the technical professionals involved with the project.
- International interest in the potential for new water supplies.
- Major efforts by OSW to disseminate the information developed.

The factors hindering diffusion of the VTE process demonstrated at Freeport include:

- Premature implementation of the process on a demonstration scale.
- Inadequate assessment of the potential market.
- Excessive developmental work and consequent down time at the demonstration plant.
- High cost of product water.
Providing for the construction of demonstration plants for the production, from saline or brackish waters, of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses.

Whereas official Government reports show unmistakably that the United States population is multiplying at a rate which by 1960 will triple the demand for supplies of fresh water, which if not available will adversely affect the national defense by jeopardizing the economic welfare and general well-being of vast segments of the population of the United States, as well as the population of some of our territorial possessions; and

Whereas many cities, towns, and rural areas are already confronted by shortages of suitable water that impair health; and

Whereas the expanding population, industry, and agriculture of the United States are becoming increasingly dependent upon an assured augmented supply of fresh water while the future welfare and national defense of the United States rest upon increased sources of fresh water; and

Whereas research by governmental agencies, educational institutions, and private industry has brought about the evolution, on a limited scale, of methods of desalting sea water and the treatment of brackish water which give promise of ultimate economical results; and

Whereas the United States Government has the responsibility, along with safeguarding the national defense, and protecting the health, welfare, and economic stability of the country, to transform these experiments into production tests on a scale not possible of achievement otherwise; and

Whereas the Congress recognized its responsibility in this field by the enactment in 1952 of the Saline Water Act (66 Stat. 828), reaffirmed its position by the amendments to such Act in 1955 (69 Stat. 254; 1951) and the legislative history of such Acts reveals that the Congress recognized even then that the time had arrived for tackling the problem more realistically and effectively, but unfortunately the program was limited to such an extent that concrete results are not possible of attainment under the provisions of existing legislation; and

Whereas the Congress now finds it is in the national interest to demonstrate, with the least possible delay, in actual production tests the several optimum aspects of the construction, operation, and maintenance of sea water conversion and brackish water treatment plants: Now, therefore, be it

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) the Secretary of the Interior shall, pursuant to the provisions of the Act of July 3, 1952, as amended (43 U. S. C. 1951-1955), and in accordance with this joint resolution, provide for the construction, operation, and maintenance of not less than five demonstration plants for the production from sea water or brackish water, of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses. Such plants shall be designed to demonstrate the reliability, engineering, operating, and economic potentials of the sea or brackish water conversion processes which the Secretary shall select from among the most promising of the presently known processes, and each plant shall demonstrate a different process. A decision with respect to the process to be utilized in the first of these five plants shall be made by the Secretary within six months after the date of approval of this joint resolution and decisions with respect to the processes to be utilized in the
other plants shall follow at intervals of not more than three months. Each such decision shall be reported promptly to the Congress and the construction of the plants shall proceed as rapidly as is possible.

(b) The construction of the demonstration plants referred to above shall be subject to the following conditions:

1. Not less than three plants shall be designed for the conversion of sea water, and each of two plants so designed shall have a capacity of not less than one million gallons per day;
2. Not less than two plants shall be designed for the treatment of brackish water, and at least one of the plants so designed shall have a capacity of not less than two hundred and fifty thousand gallons per day; and
3. Such plants shall be located in the following geographical areas with a view to demonstrating optimum utility from the standpoint of reliable operation, maintenance, and economic potential:
   (A) At least one plant which is designed for the conversion of sea water shall be located on the west coast of the United States, at least one such plant shall be located on the east coast thereof, and at least one such plant shall be located on the gulf coast thereof; and
   (B) at least one plant which is designed for the treatment of brackish water shall be located in the area generally described as the Northern Great Plains and at least one such plant shall be located in the arid areas of the Southwest.

(c) As used in this joint resolution, the term "demonstration plant" means a plant of sufficient size and capacity to establish on a day-to-day operating basis the optimum attainable reliability, engineering, operating, and economic potential of the particular sea water conversion process or the brackish water treatment process selected by the Secretary of the Interior for utilization in such plant.

Sec. 2. The Secretary of the Interior shall enter into a contract or contracts for the construction of the demonstration plants referred to in the preceding section, and the Secretary shall enter into a separate contract or contracts for the operation and maintenance of such plants. Any such operation and maintenance contract shall provide for the composition by the contractor of complete records with respect to the operation, maintenance, and engineering of the plant or plants specified in the contract. The records so compiled shall be made available to the public by the Secretary at periodic and reasonable intervals with a view to demonstrating the most feasible existing processes for desalting sea water and treating brackish water. Access by the public to the demonstration plants herein provided for shall be assured during all phases of construction and operation subject to such reasonable restrictions as to time and place as the Secretary of the Interior may require or approve.

Sec. 3. The Secretary is authorized to accept financial and other assistance from any State or public agency in connection with studies, surveys, location, construction, operation, or other work relating to saline or brackish water conversion problems and facilities for such conversion, and to enter into contracts with respect to such assistance, which contracts shall detail the purposes for which the assistance is contributed. Any funds so contributed shall be available for expenditure by the Secretary in like manner as if they had been specifically appropriated for purposes for which they are contributed, and any funds not expended for these purposes shall be returned to the State or public agency from which they were received.

Sec. 4. The authority of the Secretary of the Interior under this joint resolution to construct, operate, and maintain demonstration plants shall terminate upon the expiration of seven years after the date on which this joint resolution is approved. Upon the expiration
September 2, 1958 - Pub. Law 85-883
22 Stat. 1708.

of such seven-year period the Secretary shall proceed as promptly as practicable to dispose of any plants so constructed by sale to the highest bidder, or as may otherwise be directed by Act of Congress. Upon such sale, there shall be returned to any State or public agency which has contributed financial assistance under section 3 of this Act a proper share of the net proceeds of the sale.

Sec. 5. The powers conferred on the Secretary of the Interior by this joint resolution shall be in addition to and not in derogation of the authority conferred on the Secretary by the Act of July 3, 1952, as amended (42 U. S. C. 1951-1959). The provisions of such Act, except as otherwise provided in this joint resolution, shall be applicable in the administration of this joint resolution.

Sec. 6. When appropriations have been made for the construction or operation and maintenance of any demonstration plant under this joint resolution, the Secretary may, in connection with such construction or operation and maintenance, enter into contracts for construction, for materials and supplies, and for miscellaneous services, which contracts may cover such periods of time as he shall consider necessary but under which the liability of the United States shall be contingent upon appropriations being available therefor. Unobligated appropriations heretofore made to carry out the Act of July 3, 1952 (66 Stat. 838), as amended (42 U. S. C. 1951 and following) shall be available for administrative and technical services, including travel expenses and the procurement of the services of experts, consultants, and organizations thereof in accordance with section 16 of the Act of August 3, 1946 (60 Stat. 878), as amended (42 U. S. C. 25a), in connection with carrying out the provisions of this joint resolution.

Sec. 7. There are hereby authorized to be appropriated such sums, not in excess of $10,000,000, as may be necessary to provide for the construction of the demonstration plants referred to in this joint resolution, together with such additional sums as may be necessary for the operation and maintenance of such plants, and the administration of the program authorized by this resolution.

Approved September 2, 1958.
BIBLIOGRAPHY


-----, "Desalting Plants Inventory Report No. 4," March 1973a.


DIAL-A-RIDE TRANSPORTATION SYSTEM

by

Bruce F. Goeller and Patricia D. Fleischauer
CONTENTS

Section

1. INTRODUCTION TO DIAL-A-RIDE TRANSPORTATION .................. H-1
   Market Context .................................... H-1
   The Dial-A-Ride Concept .......................... H-1
   Market Roles for DAR ............................. H-4
   The Economics of Dial-A-Ride ..................... H-5
   Guide to the Remainder of This Note ............. H-7

2. ORGANIZATION OF THE HADDONFIELD DIAL-A-RIDE
   DEMONSTRATION ..................................... H-8
   Goals ............................................. H-8
   Site Selection .................................... H-10
   Site Characteristics ............................... H-11
   Technological Background ......................... H-13
   Organizing and Managing the Project ............. H-17
   Funding and Monitoring ........................... H-21

3. DIAL-A-RIDE OPERATIONS AND OUTCOMES IN HADDONFIELD ....... H-23
   Basic Operations .................................. H-23
   Outcomes for Manually Controlled Dial-A-Ride .... H-24
   Outcomes for Computer-Controlled Dial-A-Ride .... H-30
   Evaluation ........................................ H-34

4. DISSEMINATION OF INFORMATION FROM THE HADDONFIELD
   DIAL-A-RIDE ....................................... H-47
   Dissemination Mechanisms .......................... H-47
   Evaluation ........................................ H-51

5. DIFFUSION OF DIAL-A-RIDE TECHNOLOGY .......................... H-53
   Diffusion ......................................... H-53
   Evaluation ........................................ H-53

Appendix

A. DETAILED TECHNOLOGY CHARACTERISTICS ....................... H-57
B. TEXT OF "THE 13(c) AGREEMENT" ............................. H-59
C. TECHNOLOGY-SHARING ACTIVITIES OF THE U.S. DEPARTMENT
   OF TRANSPORTATION ............................... H-61
D. DEMAND-RESPONSIVE TRANSPORTATION SYSTEMS OPERATING,
   PLANNED, OR UNDER STUDY IN OCTOBER 1973 ............ H-65

REFERENCES ............................................. H-73
1. INTRODUCTION TO DIAL-A-RIDE TRANSPORTATION

MARKET CONTEXT

As it has grown and dispersed, the U.S. population has become increasingly dependent on the private automobile for transportation service. In the present, although much of this population receives adequate transportation service from the automobile, large segments (such as the handicapped, the elderly, and the poor) do not. In the future, problems with highway congestion, air pollution, and energy scarcity will probably reduce the quality and limit the quantity of transportation service provided by the private automobile. Concern about the private automobile's present and prospective problems has resulted in a substantial and growing demand for adequate public transportation.

This demand has not been met. Conventional bus and rail systems, operating on a limited number of fixed routes and requiring a high level of utilization to break even, cannot adequately serve the relatively widespread and low-density areas where most people now live. As alternatives, a wide variety of para-transit approaches have been proposed, including computer-matched carpools and jitneys. One of the most promising concepts is demand-responsive transportation (DRT). Although DRT represents a family of systems, its most famous member is the Dial-A-Ride system. Indeed, the generic concept is frequently--but erroneously--referred to as Dial-A-Ride rather than demand-responsive transportation.

THE DIAL-A-RIDE CONCEPT

Dial-A-Ride (DAR) is a public transportation system. It provides on-call, door-to-door service, like a taxi. But, unlike a taxi, small buses are used rather than automobiles, and groups of passengers with similar origins and destinations share the vehicle (and its costs) rather than traveling separately. DAR is thus a hybrid of the conventional taxi and conventional bus service: The intent is to provide the convenience of a taxi at a fare only slightly higher than conventional bus.
In the Dial-A-Ride concept, convenience is of paramount importance. On-call service allows people to make a trip when they wish rather than when the schedules for conventional bus/rail permit. Door-to-door service eliminates long walks to and from bus and rail stops, and people wait for pickup in the comfort and privacy of their own living room (or whatever their origin is) rather than at some public and open bus/rail stop.

System Operation and Components

The basic operation of a Dial-A-Ride transportation system involves: the patron telephoning in a request for service, specifying his origin, destination, and desired departure time; the control center dispatching a vehicle to pick up the patron at approximately his desired departure time and carry him to his destination; and the vehicle following a route that will accommodate other patrons whose service requests are geographically and temporally compatible. The number of intermediate stops a DAR vehicle makes while carrying one patron from his origin to destination will depend not only on the number of other patrons along the selected route, but also upon the vehicle capacity, the time of day, and the type and level of service provided.

The basic components of a DAR transportation system are therefore:

(1) A fleet of vehicles,
(2) A means of communication between patron and service,
(3) A means of communication between the service and the vehicle drivers, and
(4) A control center.

The control center takes trip requests, makes scheduling and routing decisions, dispatches vehicles, and administers the system (e.g., performs record keeping and revenue accounting). All DAR systems are built from these components. But different technological choices may be made for these components and different organizational structures may obtain. DAR systems may operate under different forms of management (public or private), serve areas of different size and demography, provide different types of service, and fulfill different market roles.
Types and Patterns of Service

DAR systems generally offer both preplanned and responsive service. In responsive service, the patron's request is made just before the trip. In preplanned service, the patron's request is made somewhat in advance—the night before, for example; an important variation of preplanned service is subscription service where a patron makes one request to initiate service on a daily or other regular basis.

DAR may offer three types, or patterns, of service: many-to-one, one-to-many, and many-to-many.

The many-to-one, or gather, type of service provides transport from multiple origins such as residences to a common destination such as a shopping center or transit station. This type of service often involves picking up a large group of people daily at a particular time and delivering them to a particular point; the morning pickup of commuters would be an example. For this type of service, a schedule of stops can be preplanned and given to the driver each morning.

The one-to-many, or scatter, type of service provides transport from a single origin such as a transit station to multiple destinations such as residences; an example would be the evening distribution of commuters to their homes. In this type of service, the driver records the addresses as people board the vehicle and then plans his own route and schedule of stops.

The many-to-many type of service is similar to a limousine operation. It is generally a responsive, rather than preplanned, service where a person calls the control center, giving his desired origin and destination, and the control center dispatches a vehicle to the pickup location. Since the driver reports to the control center by radio when each pickup and delivery is made, the control center knows at all times where the bus is and where it is going next.

These particular services may be used alone or in combination in a particular service area. The more complex their mixture, the greater the demands put on the scheduling and routing functions of the control center. With relatively sophisticated control, it is possible to insert
trips which are essentially many-to-many within the preplanned stops of
a gather or scatter pattern of service, thereby improving vehicle pro-
ductivity and reducing many-to-many passenger waiting times.\textsuperscript{(1,2)}

**MARKET ROLES FOR DAR**

To improve the level of transportation services available to a community, DAR can perform a variety of important roles:\textsuperscript{(1)}

- *Feeder service to line-haul transit*--the collection and distribution functions to provide door-to-door service for commuters and other transit patrons cannot be performed efficiently in traditional transit operations. By using demand responsive transportation to improve the overall level of service available to transit patrons, additional demand is generated for the line-haul operations.

- *Replacement service for conventional buses in low-density areas or at periods of low demand*--demand responsive transportation provides a higher-quality service for areas or times, such as weekends and evenings, that cannot economically support traditional bus service.

- *Specialized service for the handicapped and elderly*--demand responsive transportation vehicles can be designed to accommodate wheelchairs or other special equipment for the infirm or handicapped. Many elderly persons cannot negotiate the steps or long walking distances involved in using traditional transit, cannot afford the expense of taxi fares, and do not have an automobile available. Demand responsive transportation can be tailored to their needs.

- *Substitute for or alternative to private automobile*--even for the relatively affluent, demand responsive transportation can provide an appealing alternative to driving or riding in a private auto for such trip purposes as shopping, chauffeuring children, attending meetings, and commuting to work. Demand responsive transportation adapts well to non-radial and off-peak suburban trips that are not served adequately by traditional transit, and can offer the convenience of subscription service.

- *Route rationalization*--demand responsive transportation is used to identify appropriate placement and revisions of fixed route service.

DAR may perform in any combination of these roles. Generally, DAR has been used as an autonomous system within some neighborhood or community. But it may also be used as a component of an integrated trans-
portation system for a large region, providing both feeder service to the region's conventional bus and rail system and local circulation service to the low-density parts of the region.

THE ECONOMICS OF DIAL-A-RIDE

For a DAR system, the economic viability is determined by the supply characteristics of the service and the demand characteristics of the market area in which a system is implemented. Generally, these factors interact to produce a steady level of ridership, but with a pattern of normal variations by hour, day, or season, based on local conditions. The ridership level may increase over time, as the service is tailored to suit its particular market, or change with the supply or demand variables. The object is to achieve satisfactory financial performance; satisfactory performance need not imply making a net profit, however, but does involve providing services at an acceptable level of subsidy.

Supply

DAR is labor-intensive. The control center staff and driver wages represent the major portion of operating costs. The labor costs vary primarily with hours of operation, whether or not revenue is being generated, so the economic objective of the operator is to maximize the revenue-generating capacity of each vehicle, while meeting the constraints of the service objectives. To do this, the operator manipulates the key variables of a DAR service: the size of the service area, the number and type of vehicles, the fare structure, hours of operation, operating patterns, and special services. The overall level of service is expressed in terms of wait times and travel times incurred by a patron. (As a rule of thumb, it is considered necessary to maintain the level of service such that the ratio of waiting plus travel time for a demand responsive trip to the time required to make the same trip by private automobile does not exceed 3.0.)

For economic performance, the key measure is vehicle productivity—the degree to which the fleet generates revenue—measured in terms of the
number of trips or requests per vehicle per hour. "An individual vehicle must be deployed efficiently so as to minimize mileage and time spent in picking up and transporting passengers; the fleet must be deployed efficiently so that a given fleet can accommodate as many requests for service as possible. However, there are important tradeoffs. The level of service decreases as productivity increases, so that at some point demand may be affected. Conversely, increasing the number of vehicles in an area increases the quality of service, but the marginal cost may not be offset by marginal revenue....Productivity varies with the type of service and vehicle supplied: many-to-many is typically associated with lower productivity than many-to-one or many-to-few. The maximum potential of taxis is inherently lower than that of buses, although this is offset by the lower capital and operating costs. In addition, productivity will vary with such operating parameters as average length of trip."(1)

Demand

The volume of travel on a DAR system cannot be directly manipulated by the operator. He can stimulate demand by varying such service characteristics as fleet size, fare, service area, and hours of operation. But factors that he cannot vary will also strongly influence the magnitude and nature of demand.

These primary factors are: (1) the origin and destination of trips made by the service area population; (2) the temporal distribution of these trips; (3) quality of service available via alternative modes, including private automobiles; (4) user demographic characteristics, such as age.

The limited demographic data available on users of demand responsive services indicates an emphasis on elderly and female users, although this may reflect a bias in the data.

The spatial and temporal distribution of demand is particularly important. The more concentrated the demand, in time and space, the more likely that satisfactory vehicle productivity can be achieved. The addition of subscription services to a responsive system can help improve productivity and control-center efficiency, since subscription tours can be preplanned at off-peak periods.
GUIDE TO THE REMAINDER OF THIS NOTE

Section 2 describes the organization of the Haddonfield demonstration in terms of the demonstration's goals, the selection and characteristics of the site, the technological background, and the funding and management of the project.

Section 3 describes the basic Dial-A-Ride operations in Haddonfield; summarizes the various cost, benefit, and performance outcomes of both manual and computer-controlled operations; and then evaluates the demonstration's goal attainment, success, and contributing factors.

Section 4 describes the dissemination of information from the Haddonfield demonstration and evaluates its success.

Section 5 summarizes the diffusion of Dial-A-Ride systems and evaluates the Haddonfield contribution to this process.

Several appendixes support the main text: Appendix A summarizes technology characteristics; Appendix B presents the text of the 13(c) agreement from the Urban Mass Transportation Act; Appendix C presents an overview of the technology-sharing activities of the U.S. Department of Transportation; and finally, Appendix D lists demand responsive transportation systems operating, planned, or under study in October 1973.
2. ORGANIZATION OF THE HADDONFIELD DIAL-A-RIDE DEMONSTRATION

GOALS

Demand responsive transportation in the United States began in about 1910 with touring-car jitneys. But the concept was not applied to transit until 1964 with the Peoria, Illinois, "Premium Special Service."(1) Between 1964 and 1971, about ten demand responsive transportation systems were operated in the United States. Nearly all of these were Dial-A-Ride systems. But none of them really offered gather or scatter service patterns, provided feeder service to an integrated regional transit system, or served the general market (rather than a specialized market such as the handicapped). There was thus a need for demonstrations that would consider these DAR service patterns and market roles.

There was also a need to consider possible improvements and innovations in the technology and organization of the system components. Relatively effective technology for the vehicle and for the communication between patron and control center and between control center and vehicle was available, off-the-shelf, in the form of minibuses, telephones, and short-wave radios. For these system components, only small opportunities for technological improvements appeared to exist. But, based upon the work of Daniel Roos, Nigel Wilson, and others at MIT, computerized automation of the DAR control center appeared to offer a major opportunity for technological innovation: This automation would not only involve accounting and record keeping, but also computer-assisted scheduling and routing of vehicles to increase control center capacity and efficiency.

Federal Agency Goals

To meet these needs, Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation decided to sponsor a demonstration--for which Haddonfield was eventually selected as the site--with the following goals:

(1) Gather information on the demand and costs of a public Dial-A-Ride system that provides integrated feeder service to a rapid transit
line as well as circulation service within a local area (gather and scatter as well as many-to-many service),

(2) Determine the performance maxima achievable with a manually controlled Dial-A-Ride system,

(3) Establish operational criteria for switch-over from a manually scheduled to a computer-scheduled system,

(4) Determine the parameters for a computer-scheduled Dial-A-Ride system,

(5) Establish the feasibility and gather information on the demand and costs of a computer-scheduled Dial-A-Ride system, and

(6) Disseminate the results so that other communities can determine the feasibility of DAR for their transportation problems.

This particular list of goals has been synthesized from relatively cryptic information in Refs. 1-4. A lesser but implicit goal involves making whatever modifications to the vehicle and communications components as will help the demonstration run more smoothly, safely, or reliably. Another goal, originally planned but then dropped, was to test digital as well as voice communications between the control center and vehicles.

Eldon Ziegler, UMTA's project monitor for the last half of the Haddonfield demonstration, succinctly stated that the demonstration's goals were to: (a) determine costs, ridership, revenue, and benefits of DAR; (b) reformat and report the results to share with other communities; and (c) develop, test, and evaluate a computer-based control technology, first in the many-to-many and then in the one-to-many and many-to-one service patterns. From these two lists of goals, it should be clear that the Haddonfield demonstration involves a mixture of research, development, and demonstration activities. It is primarily a demonstration activity for the manually controlled Dial-A-Ride, but with considerable development activity. It is primarily a development activity for the computer-controlled Dial-A-Ride system, but one that has the flavor of demonstration since the control-system is being developed, tested, and evaluated in a

* These were actually few-to-many and many-to-few patterns in some instances.
real-world operating environment. Indeed, Haddonfield Dial-A-Ride formally meets the Rand-ETIP project's criteria for a demonstration because its activities take place in a real-world operating environment.

Local Agency Goals

The local agency operating the Haddonfield DAR demonstration (HADAD) was the New Jersey Department of Transportation (NJDOT). From the evidence available it appears that the goals of UMTA and NJDOT were fully consonant but that there was some difference in priorities. 

Separating goals that are concerned with improving service from those concerned with gathering information, it can be inferred that NJDOT gave somewhat higher priority than UMTA to service improvement goals. Such a difference in priorities may be significant in the computer-controlled phase of the demonstration since that was primarily a development activity.

SITE SELECTION

In choosing a site for a demonstration to meet the goals mentioned above, UMTA's primary criteria were that the site contain: (1) a rapid transit interface (station) to allow DAR to operate as a transit feeder as well as a local circulation system; (2) a strongly interested local agency; and (3) a population with socioeconomic characteristics, particularly income-level, favorable to DAR. The latter two criteria stem mainly from UMTA's perception of the attributes necessary to give good Dial-A-Ride demonstrations.

The NJDOT submitted a formal proposal which detailed the virtues of Haddonfield, New Jersey, as the site for the proposed demonstration. But other agencies also submitted proposals suggesting other localities.
It is unclear how Haddonfield was selected over the other localities. In terms of meeting UMTA's site criteria, it was not unique. A major role was apparently played by John Cole, commissioner of NJDOT. Cole was well known in public transportation and in HUD, which had been the primary funding agency for conceptual and simulation research on the DAR concept. Cole personally worked very hard to get DAR to Haddonfield. Hence it may be that Haddonfield's selection was due in large measure to Cole's reputation and prior association with the agency that had funded most of the relevant research and demonstration work.

SITE CHARACTERISTICS

The Haddonfield Dial-A-Ride demonstration was located in Camden County, New Jersey, about ten miles from downtown Philadelphia. The Haddonfield Borough, which is at the center of the DAR service area, contains the Haddonfield station of Port Authority Transit Corporation (PATCO) high-speed rail line connecting Lindenwold, New Jersey, to central Philadelphia. Many of the people who live in the Haddonfield vicinity actually work in Philadelphia, which is only a 15-minute train ride away, or in Camden, which is even closer. Indeed, about ten percent of the more than 40,000 daily trips on this rail line use the Haddonfield PATCO station. Thus, one market role of the Haddonfield DAR system was to provide feeder service to the PATCO station.

Besides Haddonfield, where the service began, the service area included all of Barrington and Lawnside Boroughs and part of the Cherry Hill Township. Figure 2.1 shows the DAR service area. Note that the Cherry Hill Mall, a major regional shopping center, is shown on the map outside the service area receiving many-to-many service. However, the Cherry Hill Mall and the nearby Cherry Hill Hospital did receive considerable service from the Haddonfield DAR because they are major attractors of trips.
The Haddonfield DAR served an area of about 11 square miles containing a population of about 40,000 people, varying considerably in socioeconomic characteristics. Table 2.1 shows the socioeconomic characteristics of the various communities that comprise the service area. Each of these communities has distinctly different characteristics: Haddonfield and Cherry Hill both have high incomes, medium population densities, low black percentages, and fairly high automobile ownership. Lawnside and Barrington both have relatively low income and auto ownership; however, Lawnside is predominantly black with a low population density, whereas Barrington is almost completely white with a high population density.

The Haddonfield DAR offered service to anyone living within the service area. However, it had to compete for patrons with several other modes besides the ubiquitous automobile: A large private bus company, Transport of New Jersey, operates four conventional bus routes that crisscross the service area and focus on the PATCO station; their fares are roughly comparable (35¢ base plus additional charges) to DAR's (30¢ for most trips during much of the demonstration) and their frequencies (30 minutes during the peak period and an hour or more off-peak) are somewhat less convenient. One small taxi company is located within Haddonfield and several others are nearby; their fares are considerably higher than DAR (75¢ within Haddonfield and over 50¢ per mile outside), but their frequencies are sometimes more convenient.\(^{(5)}\)

TECHNOLOGICAL BACKGROUND

Here we shall briefly describe the various items of technology used in the Haddonfield DAR demonstration. Although they primarily involve commonplace items such as minibuses and shortwave radios, their technology base varies from a magnetized control map that is relatively primitive to a computer system that is highly sophisticated.

Vehicles

The DAR service used two types of buses. Twelve are the Twin Coach Model TC-25, equipped with air conditioning and powered by a gasoline
Table 2.1

SERVICE AREA SOCIOECONOMIC CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
<th>HADDONFIELD</th>
<th>BARRINGTON</th>
<th>LAWSIDE</th>
<th>CHERRY HILL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (sq mi)</td>
<td>3.3</td>
<td>1.5</td>
<td>1.5</td>
<td>4.6</td>
<td>10.9</td>
</tr>
<tr>
<td>Population</td>
<td>13,100</td>
<td>8,400</td>
<td>2,800</td>
<td>15,800</td>
<td>40,100</td>
</tr>
<tr>
<td>Population Density</td>
<td>4,000</td>
<td>5,600</td>
<td>1,800</td>
<td>3,400</td>
<td>3,700</td>
</tr>
<tr>
<td>No. Households</td>
<td>4,400</td>
<td>2,700</td>
<td>800</td>
<td>5,100</td>
<td>13,000</td>
</tr>
<tr>
<td>Mean Income/Household</td>
<td>$20,100</td>
<td>$12,400</td>
<td>$10,700</td>
<td>$17,200</td>
<td>$16,700</td>
</tr>
<tr>
<td>Percent Black</td>
<td>1.7</td>
<td>1.3</td>
<td>90.4</td>
<td>.4</td>
<td>7.2</td>
</tr>
<tr>
<td>Autos/Household</td>
<td>1.5</td>
<td>1.4</td>
<td>1.4</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Workers/Household</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Drivers Licenses/</td>
<td>1.9</td>
<td>1.8</td>
<td>1.9</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Household</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Ref. 7.
engine with automatic transmission. They contain 17 peripheral seats and cost about $24,000.

When DAR service was expanded, seven smaller buses that could operate more easily on narrow streets were added to the fleet. These were Mercedes-Benz Model 0309D's, having diesel engines and manual transmissions, seating 10 people, and costing about $17,000 each.\(^5\) (Appendix A presents some added details on these vehicles.)

Communications Equipment

The radio system is made by Motorola, and is described in Appendix A. Basically, it is a duplex unit with tone-coded squelch and selective-call features. A base radio is contained in the control center, and a mobile radio is located on each vehicle. Whenever a bus reaches a particular destination, the driver radios the dispatcher and is given additional stops to make.

During the demonstration, a "no hands" unit was developed for the buses so drivers could communicate safely while the bus was moving. It consists of a speaker near the driver's left ear, a boom microphone near his mouth, and a transmit/monitor switch near his foot.\(^2\)

Hardware for the Manual-Control System

A number of useful devices were specially designed and built for the manual control system developed in Haddonfield--of particular interest are the dispatch console, load indicators, and magnetized control map. The dispatch console is located on the dispatching desk. It receives trip tickets from the scheduler in color-coded dispatching slots for each vehicle, has positions for pickup and delivery ticket queues, displays lights to show which vehicles are in service, and provides a load-indicator switch for each vehicle.\(^6\)

The load indicators are digital displays, one for each vehicle, that show the number of passengers on each vehicle. Whenever the dispatcher is informed by a driver of a pickup or delivery, he changes the appropriate load indicator. The load indicators are located in a panel on the wall next to the magnetized control map.\(^6\)
The magnetized control map is used to make routing decisions for the buses. It consists of a large metal-backed map and magnetic pieces:

...The magnetic pieces hold trip tickets containing customer trip data—one piece denoting an origin and another, of a different kind, a destination. When a trip is assigned, colored markers corresponding to the vehicle are placed on both pieces. These markers also serve as pointers to the vehicle's next stop and effectively trace out a tentative route for each vehicle. When the bus arrives at a stop, the driver notifies the control center which updates his position on the map and, in turn, notifies him of his next stop. The map, therefore, represents quite accurately the true state of the system, i.e., vehicle position, customers on board, and waiting customers. Given this full view of all tentative routes, they could be altered to accommodate new trip requests.

It should be noted that the manual-control system was designed to be compatible with and provide a backup for the computer-controlled system.

Computer System Hardware

The computer is a Westinghouse Model 2500, with a relatively fast cycle time and a 32,000-word memory. It has various peripheral devices including tape and disk input and storage, card reader and line printer, and teletype and CRT terminals. See Appendix A for details. This hardware has been estimated to rent for about $50,000 annually.

Software for the Computer-Controlled System

Software is generally considered a high technology item, just as the computer itself is; without the software that directs it in the solution of a problem, the computer is merely a pile of junk. Accordingly, we shall discuss the Haddonfield software as a technological innovation.

The software for the computer control of the Haddonfield DAR system was intended to schedule and route the vehicles, as well as keep administrative and accounting records. Whenever a customer telephoned the
control center to request a trip, the software was intended to operate as follows:\(^{(2)}\)

When a new trip request is entered into the computer, it will search through its list of the previously planned bus tours and will insert the new request at the "best" point during the tour of the "best" bus. The term "best" here means that insertion would cause minimum extra waiting and travel time for all customers.

As soon as a decision as to where to insert the new trip is made, the computer will print out the necessary trip information which is instantly given to the customer while he is still on the phone. The computer is programmed to try to avoid causing anyone to be picked up later than they were initially told, but if this is unavoidable, the controller will be duly notified of the change.

The computer will keep files in its core memory on the status of all vehicles and the tour lists of people assigned to be picked up by those vehicles. Records of addresses are maintained on disc file. All transactions and completed trips will be recorded on magnetic tape, and can be analyzed to provide complete operating and accounting information.

ORGANIZING AND MANAGING THE PROJECT

Once the location of the site had been selected, the choice of the local agency sponsor for the demonstration followed automatically: NJDOT. (Indeed, given the semi-monopolistic operations of urban transportation industries, the choice of a demonstration site usually implies the local sponsor.) UMTA reportedly gave NJDOT its initial funding in April 1971. Soon after, NJDOT issued three contracts for the demonstration. The first contract was with Highway Products, Inc., of Kent, Ohio, to purchase the vehicles.\(^{(6)}\)

The second contract was with Transport of New Jersey (TNJ), the largest privately owned bus company in the United States,\(^{(5)}\) to provide the drivers (who are members of the Amalgamated Transit Union, AFL-CIO) and to perform all bus maintenance (at their garage in nearby Camden).

The third contract went to a team of two private consulting firms--LEX Systems and DAVE Systems--to perform systems design and operations management for the demonstration, on-site. The team of LEX and DAVE Systems (hereafter called LEX/DAVE) apparently got the contract by
responding to an RFP from NJDOT. (But they may have also submitted an unsolicited proposal to UMTA for the Haddonfield work.)

LEX/DAVE teamed up because of their complementarity; LEX Systems had system design capability, while DAVE Systems had been developing relevant technology and doing DAR simulation work for two years before Haddonfield.

The LEX/DAVE contract was signed in early August 1971. Soon after, four staff members arrived in Haddonfield, established a project office, and began laying out the administrative and technical organization. This organization comprised a part-time program manager; a full-time site manager for system design; a part-time assistant site manager to develop operating and training procedures; two supervisors to train and manage, respectively, the control center personnel and the vehicle operators; and an administrative/public relations manager. Other experts on the LEX/DAVE staff were brought in as needed. (6)

By February 1972, controllers had been hired, and Haddonfield Dial-A-Ride was ready to begin its initial operation under manual control. However, because of a local bus drivers' strike, service operations did not really begin until May 1972. From May 1972 to March 1975 buses were operated every day of the year, 24 hours a day. (6)

Besides its contract to NJDOT to sponsor the demonstration, UMTA gave a separate contract to The MITRE Corporation in McLean, Virginia, to analyze the demand and other system data collected by LEX/DAVE and to evaluate the overall demonstration.

Although the project was originally conceived and described in terms of somewhat different phases, it has actually evolved with the following three phases: (2,3)

- Phase I covers approximately the first year of operation ending January 1973. It was primarily concerned with establishing and improving the manually controlled service.
- Phase II covers the second year of operation, ending January 1974. It was primarily concerned with expanding the manually controlled service and gearing-up for computer-controlled scheduling.
• Phase III covers approximately the third year of the demonstration. Although the demonstration was originally planned to terminate in October 1974, it was extended three times—until March 1975—to allow smooth transition to local support and probably also to allow completion of certain reporting tasks.

During Phase I, LEX Systems served as the prime contractor, with its president, Louis Davis, as demonstration manager; DAVE Systems served as an associate contractor, with its president, Anthony Simpson, as site manager.

In September 1972, UMTA announced that three sole-source contracts would be let for the development of the computer-scheduling system. These contracts were awarded to the University of Pittsburgh, Westinghouse, and to MITRE. There was some concern about the contract that went to MITRE because (1) MITRE was already the planning and evaluation contractor and by virtue of the additional contract would be in the position of evaluating its own work, and (2) MITRE accepted the MIT computer-scheduling philosophy while LEX did not and hence had designed the Haddonfield system to reflect a different philosophy. There was also some concern about the difficulty of modifications to the Westinghouse 2500 computer's system software.

During Phase II, LEX/DAVE jointly served as the prime contractor. A representative from LEX served as the site manager, into which job we infer that the demonstration manager's responsibilities had been incorporated. As a result of its new contract, MITRE had primary responsibility for developing and installing the computer programs for the computer-controlled scheduling and LEX/DAVE supported MITRE in a management and operations capacity.

The basic organization for the project during Phases I and II is shown by Fig. 2.2 (one change, made in Phase III, will be mentioned subsequently).

LEX and DAVE Systems have always been two separate companies. They began a close relationship with the Haddonfield joint venture and continued it in about four subsequent studies. This close relationship
Fig. 2.2--Organization of Haddonfield DAR
lasted about a year and a half, well into Phase II; at one time LEX even bought some stock in DAVE Systems, but it has since been sold. Subsequently the relationship dissolved with LEX and DAVE each deciding that it would be to their advantage to team with different consultants.

The splitting up of LEX and DAVE, however, caused problems for NJDOT in forcing it to deal with separate entities. To solve them, NJDOT hired Wilbur Smith Associates to become the prime consultant. Significantly, this happened near the end of Phase II when the design, training, and operation of the manually scheduled system was essentially complete.

From that point on, for about the last year and a half of the project, the site manager was Colonel Kerkering from Wilbur Smith Associates. Kerkering and Wilbur Smith got the site manager job as a result of a separate and earlier contract which Wilbur Smith had done for the State of New Jersey studying costs and organization of Dial-A-Ride. In the course of this study, separate from the demonstration, Wilbur Smith learned much about Dial-A-Ride and Haddonfield in particular. At the same time, the State came to know the work of Kerkering and Wilbur Smith Associates. Thus when the LEX/DAVE split came, Wilbur Smith was brought in as the site manager.

**FUNDING AND MONITORING**

UMTA was the federal funding source and provided about $5 million to the NJDOT. The NJDOT mainly served as a conduit for the money to the demonstration site but contributed $420,000 worth of new vehicles. We estimate the local contribution, from fares, as $250,000. We estimate the total federal contribution, through the termination of the demonstration, at about $10 million; this includes monies expended for concept and software development and for evaluation as well as for operation of the demonstration.

Although this is the largest DAR demonstration thus far undertaken, it is, by UMTA's standards, a medium-sized demonstration in terms of funding. UMTA's demonstration budget is currently running between 20 and 30 million for fiscal 1975.
With respect to monitoring, there were two UMTA monitors during the Haddonfield project, Marcel Zobrack and Eldon Ziegler. UMTA's monitoring was mainly by personal contact, with site visits being made by UMTA people and Washington visits being made by demonstration people. For NJDOT, Warren Moore served as project officer.
3. DIAL-A-RIDE OPERATIONS AND OUTCOMES IN HADDONFIELD

BASIC OPERATIONS

The Haddonfield Dial-A-Ride system was operated continuously from May 1972 to March 1975.* (Although it nominally began in February 1972, it did not really begin regular operations until May because of a strike by local transit workers.) Dial-A-Ride service was available at any time of the day to anyone living within the service area. The system operated 24 hours a day on every day of the year, partly to conform with the rail line for which it provides feeder service. Basically, a many-to-many service was provided, on call, during every hour of the day. During the peak periods, this was supplemented by gather and scatter service to the PATCO stations, most of which is preplanned.

Although outside the service area, the Cherry Hill Mall and Hospital also received round-the-clock service from Dial-A-Ride. In Phase I, this was many-to-many service exclusively. But in Phase II, after an on-board survey of 50,000 trips revealed that nearly 60 percent of all DAR trips involved the Cherry Hill Mall or PATCO station, a fixed-route, fixed-schedule shuttle service was inaugurated between the PATCO station and the Cherry Hill Mall, with intermediate stops at the Ellisburg Shopping Center and Cherry Hill Hospital. The purpose of the shuttle service, which began in October 1973, was to increase vehicle productivity. During shuttle service hours—which were from six in the morning to ten in the evening, Monday through Saturday—the many-to-many service to the Cherry Hill Mall and Hospital was eliminated; passengers therefore had to make one transfer, which was free, between a many-to-many vehicle and a shuttle vehicle at the PATCO station. (3-5)

Besides the introduction of shuttle service, the general operation of the Haddonfield system changed in several other ways during the demonstration. First, the service area and population more than tripled. Second, when the shuttle service was introduced, the basic fares were cut in half, from 60¢ to 30¢ (and to 15¢ for senior citizens).

Third, the number of vehicles increased about 60 percent (from 12 to 19), and the number of passenger seats about 36 percent (from 195 to 265).

*The original termination date of October 1, 1974, was extended three times.
OUTCOMES FOR MANUALLY CONTROLLED DIAL-A-RIDE

Without attempting to be exhaustive, we shall mention and briefly discuss some of the various outcomes, in Haddonfield, of the Dial-A-Ride system operation under manual control; these outcomes include ridership, service quality, vehicle productivity, various costs, and revenue. Some of the effects, primarily on service quality, of the various operational changes are shown in Table 3.1. Information about costs is shown in Table 3.2, revenues and ridership in Table 3.3, and cost-revenue comparisons in Table 3.4.

Ridership

During the second year of operation, nearly 300,000 trips were made on the DAR system. (Ridership might have been several thousand higher except for two strikes, lasting about three weeks, on the PATCO rail line.) This ridership represents about three percent of all trips for the service area. Based upon several on-board surveys, \(^{(2,3)}\) it appears that: (1) about 20 percent of the trips being made on Dial-A-Ride would not have been made if Dial-A-Ride did not exist; (2) about half the trips were diverted from private automobiles or taxis; and (3) many of those using Dial-A-Ride consider it more a "necessity" than a "convenience," since about 55 percent had no driver's license and 30 percent had a license but no car.

Although relatively few commuter trips were attracted to Dial-A-Ride originally, despite this being a major objective, more than 40 percent of its trips were for purposes of commuting to work or school by late in 1973. (It has been suggested that this indicates that the DAR patrons may be gaining confidence in system reliability.)\(^{(4)}\)

When the service began, most of the service was by the many-to-many pattern, which had relatively low productivity. By the beginning of Phase II, DAR ridership was about 83 percent by many-to-many, 2 percent by gather, and 15 percent by scatter service patterns; by the end of Phase II, it was 53 percent many-to-many, 6 percent gather, 12 percent scatter, and 29 percent shuttle.
# Table 3.1

**EFFECTS OF DIAL-A-RIDE CHANGES (3)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>PHASE I, Last Part</th>
<th>PHASE II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2/1/73-3/30</td>
<td>3/31-8/17</td>
</tr>
<tr>
<td><strong>Weekly Ridership</strong></td>
<td>4,299</td>
<td>4,588</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td>6.0</td>
<td>6.2</td>
</tr>
<tr>
<td><strong>(Riders/Vehicle-Hour)</strong></td>
<td>17.2</td>
<td>17.9</td>
</tr>
<tr>
<td><strong>Wait Time</strong></td>
<td>11.7</td>
<td>12.1</td>
</tr>
<tr>
<td><strong>(Minutes)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ride Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(Minutes)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pickup Time Deviation</strong></td>
<td>-0.2</td>
<td>-2.7</td>
</tr>
<tr>
<td><strong>(Minutes) (- = Early; + = Late)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Revenue</strong></td>
<td>$3.30</td>
<td>$3.30</td>
</tr>
<tr>
<td><strong>($/Vehicle-Hour)</strong></td>
<td>$15.40</td>
<td></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>($/Vehicle-Hour)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.2
DIAL-A-RIDE COSTS (3)
February 1973—January 1974

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>*Cost Per Vehicle-Hour (In Service)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel and Oil</td>
<td>$22,500</td>
<td>$0.44</td>
<td>2</td>
</tr>
<tr>
<td>Tires</td>
<td>7,500</td>
<td>0.15</td>
<td>1</td>
</tr>
<tr>
<td>Parts</td>
<td>47,000</td>
<td>0.93</td>
<td>5</td>
</tr>
<tr>
<td>Insurance</td>
<td>31,200</td>
<td>0.61</td>
<td>3</td>
</tr>
<tr>
<td>Maintenance Labor</td>
<td>107,900</td>
<td>2.13</td>
<td>11</td>
</tr>
<tr>
<td>Driver Labor</td>
<td>539,800</td>
<td>10.63</td>
<td>55</td>
</tr>
<tr>
<td>Control Room</td>
<td>156,100</td>
<td>3.03</td>
<td>16</td>
</tr>
<tr>
<td>General and Administrative</td>
<td>65,100</td>
<td>1.28</td>
<td>7</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td>$977,100</td>
<td>$19.25</td>
<td>100</td>
</tr>
</tbody>
</table>

* Assumes service 24 hours/day, 7 days/week, 4,250 vehicle-hours/month.

### Table 3.3
DIAL-A-RIDE REVENUES (3)
February 1973—January 1974

<table>
<thead>
<tr>
<th>Month</th>
<th>Riders</th>
<th>Revenue</th>
<th>Average Fare</th>
<th>Average Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>18,490</td>
<td>$10,226</td>
<td>$0.55</td>
<td>$3.06</td>
</tr>
<tr>
<td>March</td>
<td>21,223</td>
<td>10,542</td>
<td>.62</td>
<td>3.06</td>
</tr>
<tr>
<td>April</td>
<td>21,052</td>
<td>11,605</td>
<td>.55</td>
<td>3.06</td>
</tr>
<tr>
<td>May</td>
<td>20,969</td>
<td>11,540</td>
<td>.55</td>
<td>3.10</td>
</tr>
<tr>
<td>June</td>
<td>20,846</td>
<td>11,357</td>
<td>.56</td>
<td>3.06</td>
</tr>
<tr>
<td>July</td>
<td>19,037</td>
<td>10,464</td>
<td>.55</td>
<td>4.43</td>
</tr>
<tr>
<td>August</td>
<td>21,601</td>
<td>11,912</td>
<td>.55</td>
<td>4.01</td>
</tr>
<tr>
<td>September</td>
<td>22,326</td>
<td>12,285</td>
<td>.55</td>
<td>3.93</td>
</tr>
<tr>
<td>October</td>
<td>28,537</td>
<td>11,892</td>
<td>.42</td>
<td>3.56</td>
</tr>
<tr>
<td>November</td>
<td>34,149</td>
<td>9,580</td>
<td>.28</td>
<td>3.01</td>
</tr>
<tr>
<td>December</td>
<td>36,685</td>
<td>10,395</td>
<td>.28</td>
<td>2.92</td>
</tr>
<tr>
<td>January</td>
<td>33,458</td>
<td>9,488</td>
<td>.28</td>
<td>3.16</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>297,871</td>
<td>$131,686</td>
<td>$0.44</td>
<td>$3.28</td>
</tr>
</tbody>
</table>

### Table 3.4
COSTS-REVENUE SUMMARY (3)
February 1973—January 1974

<table>
<thead>
<tr>
<th>Item</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>$977,100</td>
</tr>
<tr>
<td>Average Fare</td>
<td>$0.44</td>
</tr>
<tr>
<td>Number of Riders</td>
<td>297,871</td>
</tr>
<tr>
<td>Revenue</td>
<td>$131,686</td>
</tr>
<tr>
<td>Subsidy</td>
<td>$845,414</td>
</tr>
<tr>
<td>Subsidy per Capita</td>
<td>$21.20</td>
</tr>
<tr>
<td>Cost per Ride</td>
<td>$3.28</td>
</tr>
<tr>
<td>Cost per Vehicle-Hour</td>
<td>$19.25</td>
</tr>
<tr>
<td>Cost per Vehicle-Mile</td>
<td>$1.94</td>
</tr>
<tr>
<td>Riders per Vehicle-Hour</td>
<td>5.9</td>
</tr>
<tr>
<td>Number of Vehicles</td>
<td>12.19</td>
</tr>
</tbody>
</table>
Productivity

As the controllers and other personnel gained experience, the vehicle productivity for an average weekday rose from about 4.6 passengers per-vehicle-hour at the start of the demonstration to a steady average of about 6 during most of Phase II. It dropped to under 5 for several months—after the new buses were introduced but before the fares were reduced—and then rose sharply to about 8 after the introduction of the shuttle service. (The corresponding values ran somewhat higher for an average Saturday and somewhat lower for an average Sunday.) Considering the average duration of a trip and the average seating capacity of the buses, the buses appeared to be showing a maximum occupancy level of about 20 percent full during the afternoon peak hour, and less the rest of the day. (4)

Service Quality

Service quality is one of several factors that determines DAR ridership. Although service quality really includes a combination of attributes, in the Haddonfield demonstration it was analyzed solely in terms of time: the waiting time, the riding time, and the deviation in pickup time. (The pickup time deviation is the difference between the time the vehicle actually arrives and that promised by the dispatcher.)

During Phase II, with the various operational changes, the average waiting time was about 21 minutes, about 4 minutes more than at the end of Phase I; the average ride time increased about a minute; and the average pickup time deviation was small and stable. (4) Basically, it appears that the operational changes did not degrade service quality to a significant extent; on-board surveys have indicated that 84 percent of the riders are satisfied with their waiting times and 92 percent with their riding time. Some riders have occasionally experienced excessive waiting or riding times, but this does not seem to have caused much dissatisfaction. (2)

Revenue and Costs

Examining Table 3.2, we see that the DAR vehicles cost more than $19 per hour to operate when they were in service. Of this cost, over 80
percent was labor: 55 percent for drivers, 11 percent for maintenance, and 16 percent for control room personnel. From Table 3.4, we see that, although the system cost nearly $977 thousand to run, there was only about $132 thousand in revenue, at an average fare of 44¢; thus, the system required about $845 thousand in subsidy, which amounts to about $21 per capita for the service area and nearly $3 for each ride. The Haddonfield DAR's subsidies per-capita and per-ride were higher than for a number of conventional bus systems, but this may primarily result from higher driver wages and additional costs for development and analysis.

Technical Problems

The 24-hour-day, 7-day-a-week operation of the vehicles led to a relatively high level of breakdowns and malfunctions. Although the situation was worse in Phase I, the vehicles were available, overall, only about 84 percent of the time in Phase II; the Twin Coach availability was 83 percent and the Mercedes-Benz was 90 percent. Of the time that they were available for service, the vehicles were used about 46 percent of the time.

For the Twin Coach buses, the primary causes of downtime were engine breakdowns (34 percent) and transmission faults (19 percent); for the Mercedes-Benz buses, the primary problems were clutch failure (22 percent) and air conditioner failure (13 percent). To alleviate these problems, the preventative maintenance interval was reduced from 4000 miles, which TNJ had apparently found adequate for ordinary buses, to 3000 miles. (4)

Local Reaction

Local stores referred to DAR in their advertisements and used its availability to promote their business; see Fig. 3.1 for examples. Various local civic and school organizations recommended it as a means of getting to their functions. The local newspapers published relatively frequent and favorable reports, primarily about progress and user reaction. (4)
Fig. 3.1--DAR in Advertisements by Local Stores (3)
The response by riders to the DAR service was strongly positive, in general, according to on-board surveys. Supposedly, one of the key factors responsible for this was the excellent public relations effort put forth by drivers and controllers. The drivers have between 20 and 35 years of fixed route experience, and, at first, it was feared that they might not adapt well to the new system. With only a few exceptions, however, they quickly learned the streets and house numbers, acquired good radio discipline, and have become most enthusiastic about Dial-A-Ride.\(^{(2)}\)

**OUTCOMES FOR COMPUTER-CONTROLLED DIAL-A-RIDE**

Although originally expected to begin in 1973, computer-controlled operations did not begin until early 1974, primarily because of problems with the computer and the scheduling software. The interviews and the original draft on the computer-based system from which this Note derives were conducted late in 1974, before the final progress report and final evaluation report from Haddonfield DAR became available. Thus, although we do not think the interviews would have changed significantly, we must emphasize that they be viewed in the proper time context—after the planned, multi-month demonstration of the computer-scheduling system but before all the information had been fully digested and the final reports written. For our discussion below, we have relied on the results of our interviews as well as some extrapolations from collateral data, which were the basis for the original draft, augmented with material from the final reports.

**Ridership**

Under manual control, the general trend in ridership had been a gradual but steady increase, with a substantial increase occurring at the end of Phase II with the reduction in fares and the institution of shuttle service. Reference 5 suggests that if the same fare structure, service patterns, and service quality obtained under computer control as at the end of Phase II, then the expected ridership under computer control would be about 400,000 annually. As Table 3.5 shows, this trend
### Table 3.5
EFFECTS OF DIAL-A-RIDE CHANGES (15)
August 1973-June 1974

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8/18/73-10/19/73</td>
<td>10/20/73-1/31/74</td>
</tr>
<tr>
<td>Weekly Ridership</td>
<td>5239</td>
<td>7876</td>
</tr>
<tr>
<td>Productivity (Riders/Veh-Hour)</td>
<td>5.9</td>
<td>8.0</td>
</tr>
<tr>
<td>Avg. Wait Time (Minutes)</td>
<td>19.3</td>
<td>28.6</td>
</tr>
<tr>
<td>Avg. Ride Time (Minutes)</td>
<td>12.5</td>
<td>13.4</td>
</tr>
<tr>
<td>Avg. Pickup Time Deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Minutes; -=Early; +=Late)</td>
<td>-0.5</td>
<td>+1.7</td>
</tr>
<tr>
<td>Revenue ($/Veh-Hour)</td>
<td>$3.24</td>
<td>$2.26</td>
</tr>
<tr>
<td>Cost ($/Veh-Hour)</td>
<td>$19.25</td>
<td>$20.25</td>
</tr>
</tbody>
</table>

<sup>a</sup> Start of shuttle service and reduced fare on October 20, 1973.

<sup>b</sup> End of shuttle service on May 11, 1974 (fare unchanged).

<sup>c</sup> Does not include Sundays/Holidays.
obtained for the first part of Phase III. But then, with the transfer of the shuttle operation to TNJ in May 1974, DAR weekly ridership dropped about 30 percent, back to its previous levels, even though the reduced fares continued.

Productivity

The primary objective of the computer part of the Haddonfield demonstration was to test the feasibility of computerized scheduling and routing. If it turned out to be feasible, the primary question would then become whether computer control could provide capacity levels (i.e., how many buses it could handle) considerably higher than a manual system. On the basis of Haddonfield, Ziegler believed that the Haddonfield prototype computer-control system worked as well as the manual system at medium levels, but still had problems at high demand levels. It appears that the productivity was about equal for computer-control versus manual.*

Ronald Fisher, head of UMTA's Service and Methods Demonstrations Division, contends that the Haddonfield computer system was not effective in increasing capacity or improving productivity. However, he believes the computer-control system to be tried in the next big demonstration—Rochester, New York—will perform much better. Indeed, he expects it to be the version that they will eventually disseminate. The Rochester demonstration is being developed jointly by Fisher and Zigler.

Service Quality

MITRE reported(15) that "during the month of October 1974, the quality of service provided under computer control was at least as good as under the manual control in the many-to-many mode." Under computer control, however, there were a number of instances when buses not only were late but never arrived at all. These instances were sufficiently common that they provoked considerable negative public reaction.

*The drop in productivity from Phase II to Phase III, shown in Table 3.5, seems due primarily to the introduction of zonal operations, which took place concurrently with computer control.
Revenue and Costs

Between computer-control and manual, it is estimated by UMTA that the costs are about the same. For control cost alone, however, the computer is higher than manual; but they may be about the same when the Haddonfield computer is fully shaken-down. Reference 5, in contrast, suggests that even when shaken down, the Haddonfield computer-control system would cost about $70 thousand more annually--for computer rental and programmer salary--than the manual system because the Haddonfield service does not exceed (or stress) the capacity of its manual control system.

Extrapolating the data from Tables 3.5 and 3.6 to a full year, it appears that the annual subsidy-per-capita would increase about $10 to over $30, the annual subsidy-per-ride by about 70¢ to over $3.50, and annual subsidy to about $1.3 million. These increases reflect the drop in ridership resulting from the transfer of shuttle operations to TNJ.

Table 3.6

**COST-REVENUE SUMMARY**

February — June 1974

<table>
<thead>
<tr>
<th>Item</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>$584,064</td>
</tr>
<tr>
<td>Average Fare</td>
<td>$0.28</td>
</tr>
<tr>
<td>Number of Riders</td>
<td>151,463</td>
</tr>
<tr>
<td>Revenue</td>
<td>$42,056</td>
</tr>
<tr>
<td>Subsidy (Cost – Revenue)</td>
<td>$542,008</td>
</tr>
<tr>
<td>Subsidy per Capita/Month</td>
<td>$2.72</td>
</tr>
<tr>
<td>Cost per Rider</td>
<td>$3.86</td>
</tr>
<tr>
<td>Cost per Vehicle - Hour</td>
<td>$20.73</td>
</tr>
<tr>
<td>Cost per Vehicle - Mile</td>
<td>$1.59</td>
</tr>
<tr>
<td>Riders per Vehicle - Hour</td>
<td>5.4</td>
</tr>
<tr>
<td>Riders per Vehicle - Mile</td>
<td>0.41</td>
</tr>
</tbody>
</table>
Technical Problems

The primary technical problem was the Westinghouse computer; it took a long time to shake down its system software. The secondary problem was the shakedown and refinement of the scheduling software.

Local Reaction

The public was said to love Dial-A-Ride, but only under manual control. People had been known to call up and ask who is running Dial-A-Ride, "You or Clyde?" "Clyde," as one might guess, is their name for the computer. In addition, people have gone to meetings and asked, "Get rid of Clyde and raise the fare." The reason they felt so strongly about the computer is its perceived lower reliability and service quality.

EVALUATION

Here we shall try to evaluate the success of the Haddonfield demonstration and to draw inferences about the factors that helped or hindered it. For a complex demonstration like Haddonfield, success, by nature, is subjective and multidimensional. In terms of the outcomes of Haddonfield, as discussed above, we distinguish two kinds of success: application and information. Basically, application success is concerned with how well the technical innovation performed in providing service for its operators and users; information success is concerned with how well the demonstration performed in gathering information about the innovation's demand, costs, and benefits. (Other kinds of success relating to the dissemination of information about the innovation and to the diffusion of the innovation itself will be discussed in subsequent sections.) Reemphasizing that any evaluation of success must, perforce, be subjective, we shall now summarize some of the major actors' opinions about success, present our own conclusions, indicate some contributing factors, comment on the organizations and individuals involved, and finally prognosticate the Haddonfield Dial-A-Ride's future.
Opinions of Various Actors

Elidon Ziegler, monitor for the second half of the project and head of UMTA's Branch for Demand Responsive Systems RD&D, believes that the demonstration was both an application and information success, although there were major problems with the computer. He notes that the DAR service and public reaction to it were basically good, and that lots of information has been gathered. In terms of the anticipated results of the demonstration, he contends that actual ridership was a bit lower than surveys had originally suggested; productivity was approximately what preliminary analysis had suggested; operating costs were much greater than had been forecast, but the disparities were due to a large rise in the prevailing wage rates in a system where labor costs dominate operating costs.

Anthony Simpson, first site manager for Haddonfield DAR and president of DAVE Systems, also believes Haddonfield was a success. As an application, he admits that the service has been relatively expensive to operate, but points out that much of the expense was due to various costs and inefficiencies unique to an experimental demonstration. As an information gatherer, the study answered such questions as: Who uses the DAR system, why, and what are the relations among the factors affecting use (demand and utilization). In terms of the control technology, the manual system was perfected and the computer system advanced substantially from the state it had been in before the experiment. The computer control is by no means perfected, but they have shown that computer control will work, know what is needed in the way of further development on the algorithms, and have identified the key problems of man-machine interaction.

From the standpoint of NJDOT, the objectives of the study probably have not all been met. When the study was undertaken, NJDOT wanted to first get a manual system working and then shift to a computerized system to put into practice those things which had been only theory in the early work of Roos and others at MIT. But the computerized system supposedly does not work as well as the manual and, indeed, is not
really a production system. Furthermore, in Dial-A-Ride NJDOT had hoped for a system that was technically and economically sound. Economically it is not, largely because the cost is dominated by drivers' wages.

Ronald Fisher, head of UMTA's division concerned with DAR demonstrations for general markets, stated that the computer-control system was not effective in meeting the objectives of increasing capacity and improving productivity over the manual-control system.

The public, those who live in the Haddonfield area and ride on the DAR, accepted Dial-A-Ride in manual mode, as mentioned before. The public opinion was apparently that the demonstration was an application success—under manual control, at least.

Our Conclusions About the Haddonfield Demonstration's Success

Here we shall present our own assessments of the extent to which the Haddonfield Dial-A-Ride met its goals and the degree to which it was a success. They reflect a synthesis of the opinions of the major actors, the data gathered by the project, and our judgment.

We believe that the Haddonfield demonstration basically met all of its goals but one—determining the saturation level for a manual-control system and of determining the physical limitations of manual control. By gathering data on the manual system, designing and operating a computer-control system, and disseminating the information, the demonstration meets all the goals we have identified. Ironically, the manual system's degree of success precluded it from meeting the goal. The manual system certainly must have inherent capacity and productivity limitations. But the Haddonfield system was sufficiently well designed to substantially exceed the capacity limitations that had been predicted. This is a classic example of why goal attainment is a poor measure of application success; goal attainment really measures the quality of foresight in specifying goals rather than the performance of the system.

For the manually controlled Dial-A-Ride, we believe the ridership, service quality, and public reaction confirm that it was an application
success. We agree that it was expensive, but we think that much of the expense resulted from costs and inefficiencies unique to the demonstration. Haddonfield did not turn out to be economically self-sufficient, as NJDOT evidently hoped. But this is not exclusively a problem of DAR; essentially no public transit system in the United States is sufficiently viable to operate without a subsidy, and a demonstration like Haddonfield was unlikely to be an exception. Indeed, Ref. 2, coauthored by Gwynn of NJDOT, cites various inefficiencies inherent in the Haddonfield demonstration and then notes that: "Under these constraints, it is unrealistic to expect that the Haddonfield program could cover costs or demonstrate economic viability."

For the computer-controlled Dial-A-Ride, we believe that the unreliable operation and the unfavorable public reaction suggest that it was more of an applications failure than success. However, we do not think it was a complete failure because, when behaving reliably, the computer control appeared to have a productivity comparable to the manual system; Fisher's complaint about the computer system not showing the expected capacity and productivity improvement over the manual may reflect excessively low expectations about the performance of a manual system rather than excessively poor performance by the computer system.

Certainly, it appears that the computer itself was partly a technical failure, and the control system far from an application success. But, even for the computer, we feel that the demonstration was basically an information success.

**Contributing Factors**

Effective and thorough sales promotion appeared to be one of the major factors contributing to the Haddonfield success in attracting riders. According to LEX/DAVE, sales promotion is the most critical function in determining success except for actually operating the system; as they succinctly put it: "A demand-activated system cannot operate unless a demand exists."(6) The sales promotion program's prime objective was to convert the considerable latent demand into actual ridership; the secondary objective was to explain the service so that it
could be used effectively. Before Dial-A-Ride even started carrying passengers, intriguing newspaper advertisements appeared. (See Fig. 3.2 for an example.) And a variety of other techniques were employed during the demonstration.

In Haddonfield, it was found that the most effective promotion techniques were direct mail and personal contact. The direct mail usually took the form of a package, hand-delivered to each house, that included a folder describing the service, a self-sticking label with the system phone number, and brochures describing how to use the system for different purposes (see Fig. 3.3 for an example). The personal contact was accomplished primarily by drivers and by presentations to local groups.\(^6\) Indeed, the public relations effort put forth by drivers and controllers was mentioned earlier as a major reason for public satisfaction with service quality.

Good system design and personnel training contributed substantially, we feel, to the success of the manual system and to its providing unexpectedly high capacity. The documents describing the design and the various training aids, Refs. 6 and 8-12, show quite impressive thoroughness, logic, and lucidity.

A willingness to adapt the service to better match the users' needs and preferences was another contributing factor. Not only were numerous on-board surveys taken, public meetings held, and copious comment cards collected, but they were acted upon.

First-rate people were involved in all aspects of the project—at the federal level within UMTA, at the state level in NJDOT, and among the several contractors. Significantly, we found an impressive but rare combination of competence, candor, and helpfulness in all of our interviewees. Although we may have been singularly fortunate in our choice of demonstration, we find that this encourages us about the possible quality of other federally sponsored demonstrations in the transportation sector.

Organizational problems—arising from too many actors on the scene, UMTA, NJDOT, TNJ, MITRE, LEX, DAVE, etc.—were perhaps a major factor contributing to the computer failure. Another possible factor, as mentioned
**DIAL-A-RIDE IS COMING...**

**BUT**—it's not carrying passengers yet. The bright orange-and-beige midi-buses you see purring about the streets of Haddonfield, and parts of Cherry Hill, Lawnside, and Barrington, are involved in an operator training program. As soon as this new, personalized, door-to-door service is ready to start we'll send full details—right to the home of everyone who lives in the initial operating area. Watch for the announcement on your front door knob. Then dial your first ride and make history with us!

**Dial-a-Ride Demonstration Offices**

131 Kings Highway East

Haddonfield, N.J. 08033

Fig. 3.2—Newspaper Advertisements for DAR$^{(6)}$
CALL 795-3100

SAY "Commuter service, please"

GIVE Central Control...

- Your pick-up address
- Your destination (such as, Patco Station, or school, or place of work within Dial-a-Ride areas)
- Regular pick-up time desired
- Which days you want the service
- Your phone number
- Your name

One call does it all! Please make your commuter request call Saturday, Sunday, or in the evening whenever possible.

When you must change your commuter plans (absence, sickness, vacation, etc.) or if you wish to order other rides to other places, please call any time, 795-3100.

At Haddonfield station from 4:15 to 6:45 PM weekdays, you can ride home without calling Dial-a-Ride. Just...

- Look at Dial-a-Ride Zone Map in Station
- Locate your street zone number
- Go out to Dial-a-Ride Boarding area
- Board the vehicle with your zone number on windshield
- Enjoy the trip home; no search for your car, no struggle with traffic

At all other hours, call for your ride on free Dial-a-Ride phone in station.

Commuting with Dial-a-Ride! Commuter fare is just 50¢ a ride when you buy the 10-ride or 40-ride book at Patco Station concession stand, at various stores, or by mail from Dial-a-Ride; 131 Kings Highway East, Haddonfield, NJ 08033.

It's better to have your book of tickets in hand when you board.

If there are Dial-a-Ride people wearing orange blazers on duty, they'll be happy to help. Other times, phone in your questions on free Dial-a-Ride phone in Station.

For a ride, call 795-3100
For information, call 795-3538

Fig. 3.3--Commuter Brochure for DAR(6)
earlier, was contractor selection. Retrospectively, it could be contended that the software development contract should not have been given to a company whose design philosophy ran counter to the one LSC/DAVE had built into Haddonfield, and that a computer should not have been selected whose system software had technical problems.

For the Haddonfield Dial-A-Ride, the expenses have been inflated by various costs and inefficiencies that result from the experimental nature of the project. Additional costs for development and analysis were incurred as part of the project costs, in addition to the normal costs for operation.

Reimbursement payments were made to the local taxi companies to reimburse them for the rides they lost because of Dial-A-Ride, according to NJDOT. This is apparently the result of a particular application of the part of the UMTA act that is called "the 13(c) agreement." (If TNJ bus drivers had not been used for the Haddonfield DAR, then reimbursement payments to TNJ might have been needed also.) The 13(c) agreement (whose text is given in App. B) is intended to insure that "fair and equitable arrangements are made, as determined by the Secretary of Labor, to protect transportation industry employees from any worsening in their employment or conditions of employment as a result of the introduction of a new transportation system. Although it has some provisions for retraining, the 13(c) agreement could, in theory, inhibit the introduction of labor-saving technology and other innovations into urban transportation.

* State laws, however, may provide considerably greater inhibitions in practice. In California, for example--a provision of the State Act chartering local transit districts has led to the demise of two relatively successful DAR systems. Finding that the DAR provided "unfair competition" to local taxi companies, local courts ruled that the Orange and Santa Clara Transit Districts must either purchase the local taxi companies or cease DAR operations. (For details, see the May 1975 Motor Age and the 14 August 1975 Los Angeles Times.)
The union contract between the Amalgamated Transit Union (ATU) and TNJ was designed for fixed-schedule operation. It was not feasible to negotiate separate contract terms for Dial-A-Ride since first, it was not known whether it would be a permanent system, and second, only a small fraction of the TNJ drivers work on Dial-A-Ride. This has led to some difficulties because of fundamental differences between demand-activated and fixed-schedule operations, particularly in the rebidding of runs and the timing of lunch-breaks. With rebidding, all runs are rebid four or more times per year, with the drivers bidding in order of seniority. On one rebid, Dial-A-Ride was faced with a 40-percent turnover, and had to train the new drivers on a weekend crash program. Though the drivers cooperate in every way, it still takes an average of about 2 months for a new driver to learn the streets properly, whereas a driver can learn a new fixed-schedule route in 1 to 3 days. As the service area is expanded, the time needed to train a new driver will increase.\(^{(2)}\)

In the timing of lunch-breaks, the fixed schedules for conventional bus are constructed to allow each driver to have a convenient lunch-break during an 8-hour shift. DAR drivers are, of course, entitled to the same lunch-break because they operate under the same work rules. But, given the on-call nature of the DAR service, it is often difficult to provide the lunch-break at a convenient time. Fortunately, the DAR drivers have been very cooperative in allowing lunch-breaks to be fitted in for minimum disruption of service, sometimes driving for long periods without a break.\(^{(2)}\)

Remote garages, located at the TNJ facility in Camden rather than in Haddonfield, required that drivers travel an extra 20 minutes each way going and coming from the service area, thereby inflating costs and reducing vehicle availability. Had this been a permanent operating system rather than an experiment, a garage would have been established in Haddonfield.

Given the added costs and inefficiencies cited above, it is unrealistic, as Ref. 2 points out, to expect the Haddonfield operation to cover its costs or demonstrate economic viability, although the data gathered by the experi-
ment should permit the economics of Dial-A-Ride to be assessed. Indeed, Ref. 5, presents cost projections, under alternative organizational structures, for a permanent Haddonfield DAR system that indicate that the costs associated with the present organizational structure could be cut nearly in half by using a typical taxi company or nonunion bus company to provide the service. (See Table 3.7; we shall not bother to summarize the assumptions underlying its values except to note that the operating characteristics are similar to the situation obtaining in Haddonfield near the end of Phase II.)

Comments on Organization

There have been no organizational problems with the NJDOT-TNJ team, which was both logical and necessary: logical because TNJ had the people to do the maintenance (and, indeed, probably produced economies of scale) and necessary because NJDOT could not have gotten the project without TNJ participation because of the 13(c) agreement.
<table>
<thead>
<tr>
<th>ORGANIZATIONAL ALTERNATIVE</th>
<th>BUSES COMPUTER DISPATCHED</th>
<th>BUSES MANUALLY DISPATCHED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1975 (Million $)</td>
<td>1980 (Million $)</td>
</tr>
<tr>
<td>1. (Terminate Service)</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>2. (Consultant-TNJ)</td>
<td>$1.30</td>
<td>$1.68</td>
</tr>
<tr>
<td>3. (NJDOT - TNJ)</td>
<td>1.18</td>
<td>1.53</td>
</tr>
<tr>
<td>4. (NJDOT)</td>
<td>0.84</td>
<td>1.10</td>
</tr>
<tr>
<td>5. (TNJ)</td>
<td>1.17</td>
<td>1.52</td>
</tr>
<tr>
<td>6. (Typical Union Bus Company)</td>
<td>1.07</td>
<td>1.39</td>
</tr>
<tr>
<td>7. (Typical Non-Union Bus Company)</td>
<td>0.81</td>
<td>1.05</td>
</tr>
<tr>
<td>8. (Typical Taxi Company)</td>
<td>0.73</td>
<td>0.95</td>
</tr>
</tbody>
</table>

**NOTE:** These organizational alternatives all assume a high level of service as provided by 18 buses and are committed to minimizing wait and ride times. These figures reflect net cost (deficit) after subtracting assumed passenger revenues from operating costs.
NJDOT did a reasonable job of managing the demonstration, considering the organizational setup where maintenance fell under one group and operations under another group. A more desirable arrangement could be to operate directly through a local agency because the demonstration would benefit from local transit experience in a particular area and because one less level in the hierarchy should bring greater efficiency. This was not possible in Haddonfield because TNJ could not have handled the demonstration on its own. However, the Rochester demonstration will have locally managed transit provided by a private firm, and it is expected that it can handle its own demonstration without any trouble.

Whether the addition of Dial-A-Ride to a city's transportation system required institutional changes is not clear. UMTA's approach in Haddonfield (and elsewhere) has been based upon the following premises:

- Adoption tends to be a localized phenomenon; if you prove something in a nearby area, people are more likely to adopt it than if you prove it in a distant area.
- If you want to demonstrate a general approach you believe will prove very effective, the best way to do it is to begin with a pilot system and then expand it.
- If the manual system catches on, then the computer will follow.

The Future of Dial-A-Ride in Haddonfield

Originally, the Haddonfield Dial-A-Ride demonstration was to have stopped in June of 1973. As the computer control fell further and further behind schedule, the termination date was extended to October 1, 1974. But after considerable public reaction against termination, a bill was introduced before the New Jersey Assembly proposing that Dial-A-Ride in Haddonfield be continued, primarily with State support, in addition to contributions from the County, affected cities, and the farebox. However, after extending the October date three times, it was announced in February 1975 that the Haddonfield Dial-A-Ride project would definitely end March 21, 1975—which it did. The reason given was that the federal funds which had been the bulk of the project's support would run out on
that date and in the absence of a new source of financial support the project could not continue. At the time of the announcement, federal funding to operate the project had totaled more than $5 million with an additional $420,000 of state funds. The only possible means of continuing the project was said to be legislation which would permit the state to contribute one-third of the cost and the counties and municipalities served each to contribute one-third.
4. DISSEMINATION OF INFORMATION FROM THE HADDONFIELD DIAL-A-RIDE

DISSEMINATION MECHANISMS

The information gathered by the Haddonfield Dial-A-Ride demonstration has been disseminated by a variety of mechanisms. We shall discuss the major ones, with examples, below.

Publication Media

The Haddonfield demonstration has so far produced about a half-dozen major reports on DAR costs, benefits, and performance, and a similar number of major implementation and training manuals for the manual system. These have been advertised in UMTA's widely distributed flyers and abstracts, which are mailed worldwide to potentially interested individuals and organizations; several flyers have appeared devoted solely to Dial-A-Ride or to one of the reports from Haddonfield. All the Haddonfield reports and manuals have been made available through the National Technical Information Service. Eventually, the progress report on the computer-control phase of the demonstration and the overall evaluation report will be published, along with the documentation of the computer-control software, and given similar advertisement and availability.

Papers presenting Haddonfield data have appeared in the major journal Traffic Quarterly (e.g., Ref. 2) and at the International Conference on Transportation Research in Bruges, Belgium, in 1973. Other papers or discussions have been presented at various conferences, including several of the International Conferences on Demand Responsive Transportation. Significantly, Haddonfield data are one of the major lynch-pins of several reports attempting to synthesize and present a reasonably definitive case on DAR; the outstanding examples of these are probably Ref. 1 and the very recent Demand Responsive Transportation System Planning Guidelines, published by MITRE and sponsored by UMTA. A large number of newspaper articles have appeared about the Haddonfield DAR, not only in the local papers, but also in such diverse papers as the Sacramento Bee and the Pittsburgh Press.
Visual Media

NJDOT has put together a slide show with accompanying audio. It lasts about 15 minutes and looks quite good. They have presented this show at meetings of the League of Cities and the American Transit Association. Titled "Dial-A-Ride, the Missing Link," it describes all four Haddonfield service patterns: many-to-many, gather, scatter, and shuttle.

The Haddonfield DAR system has been featured in a number of television film clips. Probably the most interesting of these, showing both the DAR and the PATCO high-speed line, was presented in the news feature program, "New Urban Transportation Systems of the World," broadcast nationwide by the Japan Broadcasting Company in November 1972.

People Propagation*

Perhaps playing a significant role in the dissemination/diffusion process, DAVE Systems has had perhaps 40 to 50 Dial-A-Ride contracts since Haddonfield. They have so far implemented 10 systems and are under contract to install an additional 10 systems. In Haddonfield, DAVE Systems had a technological role; in other areas they have been responsible for the entire system. Haddonfield is discussed in company brochures as one of many of their projects but they do not have any specific Haddonfield brochures. Simpson spoke highly of the dissemination efforts of NJDOT and UMTA and felt that any specific promotion of Haddonfield by DAVE Systems would only be repeating the efforts of these agencies.

*The "Paul Revere rides again for Dial-A-Ride" concept:

One if by land and two if by sea,
And I in my Dial-A-Ride will be,
Ready to ride and spread the news,
Through every eligible hamlet and mews....

Incidentally, this concept receives further substantiation from the fact that the DAR had its origins in the American Revolution.
DOT's Technology-Sharing Workshop on Dial-A-Ride

DOT's first technology-sharing workshop was held in June 1973 in Philadelphia. Subject: Dial-A-Ride. One of the main reasons for picking Philadelphia as the site of the workshop was to provide an optional tour of the Haddonfield Dial-A-Ride system. The audience was a small and carefully selected mixture of 87 transit operators, planners, and local officials from communities in Federal Region III, the area around Philadelphia.

Besides the obvious hope of improving information about the new and confusing Dial-A-Ride technology, the goal of the first technology-sharing workshop was to test the workshop concept as an information delivery method. The workshop was carefully designed as the first step in this testing process. The workshop consisted of three components: (1) an overview document describing the Dial-A-Ride state-of-the-art, (2) live lectures by key people from academia, government, and the industry, and (3) special seminars, which were principally conducted with the purpose of getting feedback on the workshop process. The feedback process was facilitated by (1) providing attendees with reviewing forms for each of the live lectures and for the documentation, and (2) providing an additional copy of the overview document (besides the one the participants were allowed to keep) having special wide margins in which marginal comments, criticisms, and suggestions could be written and then returned to DOT where they were used to revise the production version of the document.

As a second step in the process, they plan to try a format which substitutes edited and abridged videotapes for many of the live lectures; indeed, 14 reels of videotapes were taken of the first conference, and these are presently being edited and woven into a detailed program for this purpose. This would allow interested groups to, in effect, hold their own conference at their own convenience and permit DOT to sponsor more conferences than the speakers' limited availability would otherwise permit.

According to information specialists within UMTA, attendees' comments on the Dial-A-Ride workshop were strongly enthusiastic. The overview
document (Ref. 1) was widely distributed by the Transportation Systems Center of DOT. This overview document has been widely acclaimed. In our opinion, this is justified, for it sets a standard that other agencies and demonstrations should emulate.

The first Dial-A-Ride workshop was funded directly by the DOT Technology Sharing Program. This year, however, the UMTA Office of Transit Management will support some workshops on other topics, as well as a repeat of the DAR workshop to be held in San Francisco. Before the UMTA Office of Transit Management was formed, there was no office in UMTA that had responsibility for disseminating the knowledge learned from all UMTA programs.

**DOT Technology-Sharing Program**

The Department of Transportation Act of 1966, among other things, requires DOT to promote and undertake development and dissemination activities for technological, statistical, and economic information about transportation systems and to consult and cooperate with local governments. From this mandate, DOT has developed a technology-sharing program which has been gaining strong impetus in the past several years and has been giving major emphasis to active, rather than passive, dissemination of information—that is, trying to get the information to those who might need it rather than merely publishing it and allowing it to languish in a report.

The DOT has a centralized coordinating function for technology-sharing, lodged within the DOT Secretary's Office of R&D Policy, as well as various formal and informal programs as sections of the operating agencies such as UMTA. In addition, DOT operates the Transportation Research Information System (TRIS) which is a coordinated network of public and private information services that specializes in data about modes, research subjects, and transportation documentation and reports. See Appendix C for a slightly more detailed overview, and Ref. 14 for a full one of DOT's technology-sharing program.
In fiscal 1976, which is the first year when the technology-sharing program will be a specific DOT budget line-item, the technology-sharing budget is $500 thousand. This does not include the money for performing the demonstrations or generating the original report, but rather for performing the coordination function and developing the various dissemination techniques.

EVALUATION

To be an information success, a demonstration project must generate good data about its technical innovation's costs, benefits, and performance. If the final progress report and the overall evaluation report for Haddonfield, when eventually published, prove consistent with the standards set by the various other Haddonfield publications, then we would rate the Haddonfield demonstration highly as an information success. Even without these additional reports, it already rates as a strong success for the manually controlled system and as a modest success for the computer-controlled system.

While information success is concerned with how well a project gathers data about an innovation's effects in a specific application, dissemination success, in contrast, is concerned with both how widely that information has been disseminated to potential adopters of the innovation and how well it has been extrapolated and packaged to inform them about the innovation's potential for their application. We believe that the dissemination activities for both the Haddonfield demonstration in particular and the Dial-A-Ride innovation in general have been outstanding in terms of quantity, quality, imagination, and relevance. DOT's state-of-the-art overview report (Ref. 1) and its technology-sharing workshops on Dial-A-Ride, both of which lean heavily on the Haddonfield demonstration, represent extraordinary milestones in technology transfer when compared against all other activities of which we are aware. Unlike the all-too-common demonstration reports which are either too general, too technical, or too specific to some unique site, these activities really help the potential adopter decide whether he wants Dial-A-Ride, what form of a system, and how to go about planning and organizing it. Moreover, for the great majority of adopters--those who decide on a manually controlled system--
the Haddonfield implementation, operation, and training manuals offer an extremely practical and helpful means of getting started. Finally, we are aware of no technology-sharing program in a federal agency that surpasses DOT's commitment, management, and approach; it appears to have great potential for successfully demonstrating and diffusing a variety of technological innovations in the transportation sector.
5. DIFFUSION OF DIAL-A-RIDE TECHNOLOGY

DIFFUSION

At the time the Haddonfield demonstration was conceived, in 1971, only a handful of demand responsive transportation systems were in operation, or indeed had ever been in operation, in the United States. By mid-1974, almost sixty demand responsive transportation systems were operating in the U.S. and Canada. Some of these were taxi- or jitney-based systems, but most are bus-based Dial-A-Ride systems. And other small-scale services are believed to be operating locally for the handicapped or elderly. (1)

Appendix D lists demand responsive transportation systems in operation, planning, or under study as of October 1973. Although most of these are in the United States, there are systems in many other countries, particularly Canada. Figure 5.1 presents a chronology of 80 demand responsive transportation systems for which key descriptive data were available, but these do not correspond exactly with those in Appendix C because of different collection dates and criteria.

Compared to all these demand responsive transportation systems, most of which are Dial-A-Ride, Haddonfield was started relatively early. Moreover, it is the biggest federally sponsored Dial-A-Ride demonstration so far, the first to focus on feeder service to an integrated transit system as well as local circulation service, the first to use computer as well as manual control, and one of the first to concentrate on the general market rather than on special markets such as the elderly or handicapped. In terms of its performance as an application, its gathering of information, and its dissemination of that information, we have rated it as relatively successful. So the question arises: By what means and to what extent did the Haddonfield demonstration contribute the rapid diffusion of Dial-A-Ride cited above?

EVALUATION

Unfortunately, we cannot really answer the above question for systems in operation because data are lacking. And it is too soon to tell


1916 Atlantic City, NJ*  
1946 Little Rock, AK (E)  
1953 Ft. Leonard Wood, MO  
1961 Hicksville, NY (E)  
1964 Peoria, IL (T)  
1967 Gothenberg, Sweden  
1968  
Feb: Boston, VA  
Sept: Flint, MI (T)  
1969  
Jan: Menlo Park, CA  
Dec: Mansfield, OH (T)  
1970  
May: Emmen, Netherlands  
July: Bay Ridge, Ontario  
Aug: Merced, CA  
Oct: Ft. Walton Beach, FL (T)  
Dec: Buffalo, NY (E)  
1971  
Jan: Columbia, MD (E)  
July: Scott-Carver Counties, MN  
Sept: Ann Arbor, MI (E)  
Oct: Batavia, NY  
Columbus, OH (E)  
1972  
Feb: Haddonfield, NJ (E)  
1973  
Jan: Kent, OH  
Apr: Sault Ste. Marie, MI  
1974  
Sept: Los Angeles, CA  
Aug: Bramalea, Ontario  
Kingston, Ontario  
Rochester, NY  
Sept: New Orleans, LA  
1975  
May: Cambridge, Ontario  
Merced, CA  
Traverse City, MI  
June: Dover, DE  
Fairfax City, VA  
Midland, MI  
Isabella County, MI  
July: Alpena, MI  
Houghton-Hancock, MI  
Richmond, CA  
Sept: Washington, DC  
Benton Harbor- 
St. Joseph, MI  
Fall: Cleveland, OH  
Santa Clara County, CA  
1976  
1977  
1978  
1979  
1980  
May: Davis, CA  
La Mirada, CA  
Helena, MT (E)  
Grand Rapids, MI (E)  
Bramalea, Ontario  
Ottawa, Ontario  
1975 Rockville, MD  
El Cajon, CA  
Hartford, CT  
Cleveland, OH  
Bentleyville, IL  
Hemet, CA  
Holland, MI  
Luddington, MI  
Mt. Pleasant, MI  
Sault Ste. Marie, MI  
La Mesa, CA  

(F) Subsequently Expanded  
(T) Terminated  

*Information on other jitney services in the United States was not available for this report.

Source: Ref. 1.

Fig. 5.1--Chronology of 80 Demand Responsive Services
what other systems may originate because of Haddonfield. Our intuition suggests that Haddonfield may eventually play a major role because of its information and application success, but this is almost a self-fulfilling prophecy in terms of a study of the process of technology diffusion. We can, however, make some comments and cite some opinions that bear on aspects of the diffusion process.

In fostering the diffusion of Dial-A-Ride systems, Zigler would rank the influence of all sources as follows: (1) the MIT work on Dial-A-Ride, (2) the big DAR conference and its report several years ago, and (3) the Haddonfield demonstration. He thinks that other influences are lesser.

Furthermore, one of the main dissemination mechanisms is the diffusion of people. This is indicated by the fact that in nearly all other DAR applications, the lead person is either from the MIT DAR group or Haddonfield. In this respect, there may be some analogy between the role of DAVE and LEX Systems and that of Marc Stragier in the Godzilla garbage truck demonstration. With the split, LEX and DAVE separately may be helping DAR fill the gap between development of technology and implementation, much as Stragier appears to be doing for Godzilla. This is probably more true for DAVE Systems which, as mentioned in Section 4, has had perhaps 40 to 50 DAR contracts since Haddonfield, have implemented 10 systems, and are under contract to install another 10.

In contrast, LEX Systems have been pursuing activities which are more in the nature of the transfer and spillover of Haddonfield technology into different policy areas and social sectors. After being replaced by Wilbur Smith Associates, LEX designed its own system. While DAVE Systems went the route of the small manual system, LEX Systems decided to pursue the large, complex system, focusing not on Dial-A-Ride but on integrated transit. This work led to the Santa Clara County project and the development of a family of models to support transportation, civil emergencies, ambulance services, police, freight forwarding, and cabs. LEX has done nothing in the way of direct diffusion or dissemination of the Haddonfield results largely because, as a small company, it has chosen to emphasize one thing.
Our distinction between application success and diffusion success appears to be an essential one. Many demonstrations, for example, will be application failures because the scale of the application is inappropriate, but the technology may still diffuse successfully.
Appendix A

DETAILED TECHNOLOGY CHARACTERISTICS

VEHICLE DESCRIPTION

12 Twin Coach 17-Passenger Buses (Model TC-25)

Length: 25 ft.
Height: 10 ft.
Width: 8 ft.
Headroom: 6 ft. 6 in.
Wheelbase: 11 ft.
Engine Type: Gasoline V-8, 200 HP
Transmission: 3 Speed Automatic
Turning Radius: 26 ft.

7 MERCEDES-BENZ 10-Passenger Buses (Model 309D)

Length: 20 ft.
Height: 9 ft. 5 in.
Width: 6 ft. 8 in.
Inside Height: 5 ft. 8 in.
Wheelbase: 11 ft. 6 in.
Engine Type: Diesel, 94 HP
Transmission: 5 Speed Manual
Turning Radius: 20 ft.

COMMUNICATIONS EQUIPMENT

1 Motorola Base Radio

RF Power Output: 90 Watts
Frequency Range: 450-470 MHz
Input Power: 117 volts AC, 50/60 Hz

19 Motorola Mobile Radios

RF Power Output: 25 Watts
Frequency Range: 450-512 MHz
Battery Drain:
Receive: 13.8V dc, 450 MA
Transmit: 13.6V dc, 14 Amps
## COMPUTER SYSTEM CHARACTERISTICS AND SPECIFICATIONS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word size</td>
<td>16 bit</td>
</tr>
<tr>
<td>Core memory: present</td>
<td>32 K</td>
</tr>
<tr>
<td>Core memory: maximum</td>
<td>64 K</td>
</tr>
<tr>
<td>Core cycle time</td>
<td>750 ns</td>
</tr>
<tr>
<td>Register (16) cycle time</td>
<td>450 ns</td>
</tr>
<tr>
<td>Card reader speed</td>
<td>300 cards per min.</td>
</tr>
<tr>
<td>Line printer speed</td>
<td>300 lines per min.</td>
</tr>
<tr>
<td>Disc storage</td>
<td>1 M words</td>
</tr>
<tr>
<td>Disc average access time</td>
<td>20 ms</td>
</tr>
<tr>
<td>Number tape units</td>
<td>2</td>
</tr>
<tr>
<td>Tape speed</td>
<td>25 in. per sec.</td>
</tr>
<tr>
<td>Number of ASR 735 teletype units</td>
<td>5</td>
</tr>
<tr>
<td>Number of CRT units</td>
<td>3</td>
</tr>
</tbody>
</table>

* Westinghouse 2500 Computer System*
Appendix B

TEXT OF "THE 13(c) AGREEMENT"

Below we quote what is commonly called "the 13(c) agreement," which is a part of the Urban Mass Transportation Act of 1964 and as such pertains only to UMTA projects. But it requires Department of Labor approval for affected projects. The potential impact of this regulation on the diffusion of a particular technology would depend on what arrangements the Secretary of Labor determined were necessary to protect the interests of transportation employees affected by the UMTA assistance.

Appendix G of the Urban Mass Transportation Act of 1964, Section 13(c), states:

It shall be a condition of any assistance under Section 3 of this Act that fair and equitable arrangements are made, as determined by the Secretary of Labor, to protect the interests of employees affected by such assistance. Such protective arrangements shall include, without being limited to, such provisions as may be necessary for (1) the preservation of rights, privileges, and benefits (including continuation of pension rights and benefits) under existing collective bargaining agreements or otherwise; (2) the continuation of collective bargaining rights; (3) the protection of individual employees against a worsening of their positions with respect to their employment; (4) assurances of employment to employees of acquired mass transportation systems and priority of reemployment of employees terminated or laid off; and (5) paid training or retraining programs. Such arrangements shall include provisions protecting individual employees against a worsening of their positions with respect to their employment which shall in no event provide benefits less than those established pursuant to Section 5(2)(f) of the Act of February 4, 1887 (24 Stat. 379), as amended. The contract for the granting of any such assistance shall specify the terms and conditions of the protective arrangements.

*49 U.S.C. 1609(c).
Appendix C

TECHNOLOGY-SHARING ACTIVITIES OF THE U.S.
DEPARTMENT OF TRANSPORTATION

Enabling Legislation & Mission:
The Department of Transportation Act of 1966 established the Department for the purpose of developing national transportation policies and programs "to provide fast, safe, efficient, and convenient transportation at the lowest cost consistent therewith."

The Act, in part, requires the Department to promote and undertake development, collection, and dissemination of technological, statistical and economic information, and also to consult and cooperate with state and local governments. From this mandate DOT says that technology sharing is basic to the department.

Technology Sharing Policy & Objectives:
The Department considers the following mechanisms and programs contributory to the technology sharing process:

- Grant-in-aid programs are part of technology sharing in that these programs provide the funds with which state local agencies can apply transportation technology.
- The planning funds which are provided come closer to being technology sharing in that they provide the wherewithal for state/local agencies to plan (analyze) what technology will be applied.
- Most directly concerned with the subject of technology sharing are the specific research, development and demonstration programs conducted by the Department.

Technology Transfer Responsibility:
The DOT has various formal and informal mechanisms and programs for sharing which will be sections on the operating agencies. The Urban Mass Transportation Administration, Federal Highway Administration and Federal Railroad Administration as well as the Transportation Systems Center and Transportation Research Information Center are described here. Within the FHWA a focal point for technology transfer is the Implementation Division.

The FY 73 Research, Development and Demonstration budget for FHWA was $30 million; for FRA $51 million; and for UMTA $76 million. FHWA had 5020 employees of which 3500 were in the field; FRA 450 and 200; and UMTA 230. TSC had a staff of 600. The FHWA Implementation Division had a budget of $890,000 and a staff of 25 professionals. In addition, each region has one man who works part time as a Regional Implementation Coordinator.

Implementation:
The Urban Mass Transportation Administration became a part of DOT in 1968 and operates a program directed toward improving public transportation services in urban areas. UMTA provides funds to buy and build capital facilities and for new transit technology development. DOT describes the logic of the UMTA program as UMTA capital grants provide funds for state and local government to apply technology; UMTA technical studies
grants provide funds for states/locals to decide on the technology to apply; the UMTA RD&D program provides the urban transit technology which can be applied; and the UMTA managerial training grants and university research and training grants provide funds for expanding local urban transit knowledge and research at local levels and at universities.

One of the recent actions of the UMTA is the establishment of a field organization. In each of the ten federal regions an UMTA representative will work closely with state and local governments.

The UMTA Transportation Planning System (UTPS) program is intended to provide state and local planners with the latest technology in transit planning tools to assist them in solving their local transit problems. The program's goals are to build computer-based tools for multimodal transportation planning, demonstrate and validate these tools in pilot cities, disseminate the tools to local planning agencies and continually reevaluate and improve the tools as a result of their application in local communities.

The Federal Highway Administration was organized by the 1966 Act and is responsible for the total operation and environment of highway systems. FHWA regularly controls from two-thirds to three-fourths of the total DOT budget with most of its funds coming from the Highway Trust Fund. The FHWA program uses an approach similar to UMTA in that the trust fund grants provide the funding for the application of technology for constructing highway systems; the Highway Planning and Research (HPR) funding, the National Cooperative Highway Research Program (NCHRPR), and the Contract Research program provide funds for States to conduct planning and research; and the FHWA R&D program provides additional technology options for eventual application.

The FHWA programs and mechanisms over the years have formed a close working relationship with State highway organizations and developed extensive highway planning and research capabilities at the state level. All of the states are partners with the FHWA in the formulation of highway research and development programs.

The Federally Coordinated Program (FCP) for Research and Development in Highway Transportation is an applied research program intended to solve relatively short-term highway problems. Its objective is to stimulate and expand the application and practical use of the products of highway research and development. The focus of the program is to use the FHWA operating offices to define and then search for solutions to problems which can be implemented.

As part of the FCP an Implementation Division was established in the FHWA in July 1972. The major function of this group is to accelerate the movement and use of usable research results across jurisdictional lines, from State to State and from Federal to State. Two major goals are foremost in achieving this objective. One is to develop an environment conducive to the national coordination and acceptance of cooperative implementation efforts by FHWA, the State highway departments and other highway users. Key factors include obtaining the interest and support of top management including both State and Federal organizations; involving engineering in the R&D process; providing solutions to the real problems of practicing engineers; and presenting research findings in a form or language that can be readily understood and immediately used by the practicing engineer (a research report does not meet this objective).

The second goal is to be able to assess in a systematic way the success of the program and the benefit realized. To meet these objectives and goals, a management plan was developed by the Implementation Division which is intended to form the basis for a coordinated, comprehensive and cooperative FHWA — State approach to implementation. It relates existing programs, such as experimental projects and demonstration projects to newer implementation activities in identification planning, packaging and promotion as well as evaluation and adoption.

A key FHWA communications mechanism is the seven volumes which describe the FCP program. These volumes are in essence a detailed description of the research needs in highway transportation. An additional document in the communication process is the annual document which describes the R&D in highway transportation which is in progress in the given fiscal year. The FY 1971 report included information such as the objective of the project, the performing organization and the funding of over 12,000 studies and/or contracts. Other communications means include a large number of advisory groups in which federal, state and local representatives engage in technology sharing as the principal focus.

The Federal Railroad Administration was also created by the 1966 Act. The purpose of FRA is to consolidate government support of rail transportation activities, provide unified and unifying national policy for rail transportation and conduct research and development activity on support of improved rail and ground transportation.

The demonstrations conducted by the FRA are designed to meet specific objectives of the High Speed Ground Transportation Act of 1965. These objectives call for measurement and evaluation of public response to such factors in transportation services as "...new equipment,
higher speeds, variations in fares, improved comfort and conveniences and more frequent service...."

The two FRA demonstrations concerned with intercity railroad passengers are located in the Northeast Corridor. One is the operation of Metroliners and improved conventional trains on the Washington-New York route. The second demonstration involves the operation of Turbo Trains on the route between Boston and New York.

The Transportation Systems Center, located in Cambridge, Massachusetts, is the technical arm of DOT. Since 1970 it has provided systems and technical planning, engineering and technical support and research and development program management. Work at the Center is carried on by three major technical directorates: Transportation Systems Concepts, Transportation Systems Development, and Technology.

As part of the effort to improve the technology sharing process of the Department, the Secretary in October 1972 formally designated the TSC as the primary focal point in support of the Department for the exchange of technical, economic and planning information with state and local sectors of the transportation community. The primary role of the Center in the technology sharing process will be to support the Department in the active and effective packaging and dissemination of the results of research, development and demonstration in the field of transportation.

The plan includes provision for bringing state/local people to TSC for training, seminars, residency programs, etc., and for making information and people from TSC available to go out to state and local areas to assist in their technology selection processes. In many instances, it is envisioned that the Center's role will require the gathering of information and support from various Modal Administrations. For example, a number of local agencies have expressed interest in learning of techniques available to improve traffic flow within their communities and have responded positively to the possibility of a seminar on the subject at TSC. For such a seminar the Center will draw support from the UMTA and FHWA on their efforts in this area in addition to any methodologies and technologies that the Center itself has developed.

The Transportation Research Information System (TRIS) is conceived as a network of public and private enterprises offering a coordinated array of information for the transportation community. These services specialize in transportation modes, transportation research subjects, and types of transportation documentation.

Components of the TRIS network include the Highway Research Information Service (HRIS), the Maritime Research Information Service (MRIS), the Transportation Noise Research Information Service (TNRIS) and the Transportation Research Activities Information Service (TRAIS).

For further information contact:
Department of Transportation
Alfonso Linhares (202) 426-4208
Chief, R&D Policy Analysis Division
Office of R&D Policy
Office for Systems Development & Technology, TST-12
400 7th Street, S.W.
Washington, D. C. 20590

Milton P. Criswell (703) 557-1800
Acting Chief, Implementation Division, FHWA
1000 North Glebe Road
Arlington, Va. 22204
Appendix D

DEMAND-RESPONSIVE TRANSPORTATION SYSTEMS
OPERATING, PLANNED, OR UNDER STUDY
IN OCTOBER 1973 *

*Personal communication from UMTA.
## DRT Systems in U.S. - As of October, 1973

### Fund Source

<table>
<thead>
<tr>
<th>Place</th>
<th>UMTA R&amp;D</th>
<th>UMTA S.D.</th>
<th>HUD M.C.</th>
<th>OEO</th>
<th>STA</th>
<th>LOC.</th>
<th>PRIV.</th>
<th>TRANSIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haddonfield, N.J.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Petersburg, Fla.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Klamath Falls, Ore.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lincoln, Neb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cranston, R.I.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naug. Valley, Conn.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Rapids, Mich.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helena, Mont.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Angeles, CA.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffalo, N.Y.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toledo, Ohio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detroit, Mich.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Habra, Calif.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Key

- **R&D**: Research & Development *(general market)*
- **S.D.**: Service Development *(minority market)*
- **M.C.**: Model Cities *(minority)*
- **OEO**: Office of Economic Opportunity

- **STA**: State
- **LOC**: Local
- **PRIV**: Private
<table>
<thead>
<tr>
<th>PLACE</th>
<th>UMTA R&amp;D</th>
<th>UMTA S.D.</th>
<th>HUD M.C.</th>
<th>OEO</th>
<th>STATE</th>
<th>LOCAL</th>
<th>PRIVATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA MIRADA, CALIF.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medford, Oreg.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carter County, Minn.</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ann Arbor, Mich.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbia, Md.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Batavia, N.Y.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>West Palm Beach, Fla.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Davenport, Iowa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Lowell, Mass.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Little Rock, Ark.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Merced, Calif.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Nassau County, N.Y.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Davis, Calif.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
### DRT Systems in U.S. - Planned - As of October 1973

<table>
<thead>
<tr>
<th>Place</th>
<th>UMTA C.G.</th>
<th>UMTA S.D.</th>
<th>HUD M.C.</th>
<th>OEO</th>
<th>STA</th>
<th>LOC</th>
<th>PRIV</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richmond, Calif.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arlington, Va.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Wilmington, Del.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plainfield, N.J.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newark, N.J.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fairbanks, Alaska</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lafayette, Ind.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orlando, Fla.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
DRT SYSTEMS IN U.S. - UNDER STUDY - AS OF OCTOBER, 1973

ALAMEDA-CONTRA COSTA COUNTIES, CALIF.
NEW ORLEANS, LA.
SAN DIEGO, CALIF.
SANTA ROSA, CALIF.
ROCHESTER, N.Y.
MINNEAPOLIS, MINN.
HUNTSVILLE, Ala.
AMBRIDGE, Pa.
PITTSBURGH, Pa.
FORT MYERS, Fla.
PASCO COUNTY, Fla.
<table>
<thead>
<tr>
<th>PLACE</th>
<th>NATIONAL</th>
<th>LOCAL</th>
<th>PRIVATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay Ridges, Ontario</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kingston, Ontario</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratford, Ontario</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Regina, Saskatchewan</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maidenstone, England</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>East Bourne, England</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Emmen, the Netherlands</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Adelaide, Aust.</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Osaka, Japan</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Harrogate, England</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Bramalea, Ontario</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ottawa, Ontario</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudbury, Ontario</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winnipeg, Manitoba</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calgary, Alberta</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DRT SYSTEMS OUTSIDE U.S. - PLANNED - AS OF OCTOBER, 1973

PLACE

HARLOW, ENGLAND

CHELMSFORD, ENGLAND

CANBERRA, AUSTRALIA
DRT SYSTEMS OUTSIDE U.S. - UNDER STUDY - AS OF OCTOBER, 1973

Edinburgh, Scot.
Castleford, Eng.
Lough Borough, Eng.
Rugby, Eng.
London, Eng.
Bath, Eng.
South Hants, Eng.
Manchester, Eng.
Stockholm, Sweden
Gothenburg, Sweden
REFERENCES


YANKEE NUCLEAR POWER REACTOR

AND

CONNECTICUT YANKEE NUCLEAR POWER REACTOR

by

William F. Hederman, Jr.
CONTENTS

Section
I. INTRODUCTION .......................................................... I-1
   Atomic Energy Acts .................................................. I-1
   The Power Demonstration Reactor Program ....................... I-2

II. CHANGING UNCERTAINTY: THE YANKEE PLANT ....................... I-6
   Initial Idea .......................................................... I-7
   Project Goals and Target Audience ............................... I-8
   Technological Uncertainty ........................................ I-8
   Pre-Project Uncertainty ........................................... I-9
   Addressing Technological Uncertainty ........................... I-10
   Operating with Technological Uncertainty ....................... I-14
   Uncertainty Reduction ............................................. I-19
   Cost Uncertainty .................................................... I-20
   Pre-Project Uncertainty .......................................... I-20
   Addressing Cost Uncertainty ..................................... I-20
   Operating with Cost Uncertainty ................................. I-22
   Uncertainty Reduction ............................................. I-22
   Demand Uncertainty ................................................ I-23
   Institutional Uncertainty ........................................ I-23
   Pre-Project Uncertainty .......................................... I-23
   Addressing Institutional Uncertainty ............................ I-24
   Operating with Institutional Uncertainty ....................... I-24
   Institutional Constraint .......................................... I-27
   Institutional Uncertainty Reduction ............................. I-27
   Uncertainty About Externalities ................................ I-28
   Pre-Project Uncertainty .......................................... I-28
   Addressing Uncertainty About Externalities ..................... I-29
   Operating with Uncertainty About Externalities ................ I-29
   Uncertainty Reduction ............................................. I-30
   Termination of Demonstration Funding ......................... I-31
   Influence of Federal Support .................................... I-31
   Aftermath ............................................................ I-31

III. CHANGING UNCERTAINTY: THE CONNECTICUT YANKEE PLANT ...... I-33
   Initial Idea ........................................................ I-33
   Project Goals and Target Audience ............................... I-35
   Technological Uncertainty ........................................ I-35
   Pre-Project Uncertainty .......................................... I-35
   Addressing Technological Uncertainty ........................... I-36
   Operating with Technological Uncertainty ....................... I-37
   Uncertainty Reduction ............................................. I-40
   Cost Uncertainty ................................................... I-40
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Project Uncertainty</td>
<td>I-40</td>
</tr>
<tr>
<td>Addressing Cost Uncertainty</td>
<td>I-41</td>
</tr>
<tr>
<td>Operating with Cost Uncertainty</td>
<td>I-42</td>
</tr>
<tr>
<td>Uncertainty Reduction</td>
<td>I-43</td>
</tr>
<tr>
<td>Demand Uncertainty</td>
<td>I-44</td>
</tr>
<tr>
<td>Institutional Uncertainty</td>
<td>I-44</td>
</tr>
<tr>
<td>Pre-Project Uncertainty</td>
<td>I-44</td>
</tr>
<tr>
<td>Operating with Institutional Uncertainty</td>
<td>I-44</td>
</tr>
<tr>
<td>Institutional Constraint</td>
<td>I-46</td>
</tr>
<tr>
<td>Uncertainty Reduction</td>
<td>I-46</td>
</tr>
<tr>
<td>Uncertainty About Externalities</td>
<td>I-47</td>
</tr>
<tr>
<td>Pre-Project Uncertainty</td>
<td>I-47</td>
</tr>
<tr>
<td>Addressing Uncertainty About Externalities</td>
<td>I-48</td>
</tr>
<tr>
<td>Operating with Uncertainty About Externalities</td>
<td>I-48</td>
</tr>
<tr>
<td>Uncertainty Reduction</td>
<td>I-49</td>
</tr>
<tr>
<td>Termination of Demonstration Funding</td>
<td>I-49</td>
</tr>
<tr>
<td>Influence of Federal Support</td>
<td>I-49</td>
</tr>
<tr>
<td>Aftermath</td>
<td>I-50</td>
</tr>
<tr>
<td>IV. OBSERVATIONS AND CONCLUSIONS</td>
<td>I-51</td>
</tr>
<tr>
<td>Yankee-Connecticut Yankee Comparison</td>
<td>I-51</td>
</tr>
<tr>
<td>Goals</td>
<td>I-51</td>
</tr>
<tr>
<td>States of Uncertainty</td>
<td>I-51</td>
</tr>
<tr>
<td>Effect on Potential Adopters</td>
<td>I-52</td>
</tr>
<tr>
<td>Other Comparisons</td>
<td>I-53</td>
</tr>
<tr>
<td>With Other Nuclear Projects</td>
<td>I-53</td>
</tr>
<tr>
<td>With Demonstrations for Other Regulated Potential Adopters</td>
<td>I-55</td>
</tr>
<tr>
<td>Lessons for Demonstrations</td>
<td>I-55</td>
</tr>
<tr>
<td>Risk-Sharing</td>
<td>I-55</td>
</tr>
<tr>
<td>Private-Sector Initiative</td>
<td>I-56</td>
</tr>
<tr>
<td>Regulatory Flexibility</td>
<td>I-57</td>
</tr>
<tr>
<td>R&amp;D Experience of Personnel</td>
<td>I-57</td>
</tr>
<tr>
<td>Other Lessons</td>
<td>I-57</td>
</tr>
<tr>
<td>Implications for the Rand ETIP Study</td>
<td>I-58</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>I-61</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

This paper presents the case studies of two civilian nuclear power plants built as projects in the Atomic Energy Commission's Power Demonstration Reactor Program (PDRP). The two plants are Yankee and Connecticut Yankee.

In 1956, the Yankee reactor project, to be located in Rowe, Massachusetts, was awarded the first project contract in the first round of the PDRP. It began supplying electrical power in 1961. In 1962, Connecticut Yankee, to be located in Haddam Neck, Connecticut, was awarded a contract as one of the modified third round PDRP projects. It first supplied electricity in 1967.

ATOMIC ENERGY ACTS

The Atomic Energy Commission (AEC) was instructed by Congress to pursue the development of civilian uses of nuclear energy. Federal responsibility for such development was first recognized in the Atomic Energy Act of 1946.

The Atomic Energy Act of 1954 clarified and broadened this responsibility and also allowed private ownership of nuclear facilities for the first time. The Act's goals included provision of an R&D program "to encourage maximum scientific and industrial progress" and of a program of international cooperation. The Act also called for

a program to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public.¹

Other provisions of this Act and "many other Acts of Congress" expanded these goals and provided the means to implement the programs.

There has been AEC-sponsored research on non-power producing uses of nuclear energy, such as radioisotopes, but power generation was viewed

¹Section 3d of the Atomic Energy Act of 1954 cited in [1, p. 104].
as the most promising peaceful use of nuclear power for "conventional tasks or extensions of them." The AEC's program first aimed at obtaining basic scientific and engineering data that would prove technical feasibility and safety, and then at demonstrating the actual or potential economic feasibility of the more promising approaches.

Prior to the opening of nuclear facility ownership to the private sector, the AEC, with JCAE encouragement, began a five year "experimental" program to develop civilian power reactors in 1953. Before the Atomic Energy Act of 1954, construction had started on several experimental power-producing reactors on AEC sites and the Shippingport reactor on a utility grid. The Atomic Energy Act revisions in 1954 encouraged industrial cooperation and opened the way for the Power Demonstration Reactor Program, which extended this five year program.¹

THE POWER DEMONSTRATION REACTOR PROGRAM

Since these two projects received PDRP funds, it is important to have an overview of this program. In the spring of 1953, the chairman of the AEC urged the Joint Committee on Atomic Energy (JCAE) to encourage private sector involvement in a national effort to develop economic nuclear power at an early date. The next AEC chairman, Lewis Strauss, also supported this policy. Up until that time, there had been some industry-AEC cooperation, but this had been for dual-purpose (power generation and plutonium production) plants.

The AEC had responded to a JCAE request for a formal plan for nuclear power development with a plan involving several small and experimental reactors and the Shippingport reactor, the first "large-scale" (50 Mwe)² nuclear power plant. After passage of the Atomic Energy Act of 1954, which amended the 1946 Act and permitted private ownership of nuclear reactors and private use of nuclear fuels and information, and through legislation introduced by members of the JCAE [31, p. 38], the

¹Summary of "Civilian Nuclear Power, A Report to the President-1962," in [1, pp. 103-105].
²Mwe = megawatts of electricity.
AEC developed the "Power Demonstration Reactor Program" in early 1955. By offering financial incentives to cooperating utilities, the AEC intended to encourage the construction of several central-station power plants. More explicitly, the PDRP was "to encourage further the increased industrial participation in the peacetime program envisioned in the 1954 law" [2, p. xii]. Under the program plan, the AEC would consider providing cooperation in such forms as waiving charges for loan of materials, R&D assistance in AEC laboratories or R&D contracts for technical and economic data resulting from work on a demonstration reactor. Such aid was considered within the Commission's limits of available funds. The AEC wanted this program "to bring private resources into the development of engineering information on the performance of nuclear power reactors and to advance the time when nuclear power (would) become economically competitive" [2, p. xii].

PDRP was integrated into the ten-year plan announced by the AEC in 1960 (effective 1958 to 1968). The PDRP presented a coordinated program of research, development, and construction. The boundaries of the PDRP are somewhat fuzzy; however, the main thrust of this program was presented through several "rounds" of invitations from the AEC for cooperative proposals from the utility industry.

In January 1955, the AEC issued the first invitation of the PDRP program. For this round, plant size or type was not specified. Proposals were to be received by April 1, 1955. The AEC cooperation to be considered was:

1. Waiving the established Commission charges for loan of source and special nuclear materials up to an agreed upon amount for a period up to seven years from July 1, 1955. The proposers would pay for all material consumed and for services performed for them by the AEC.

2. Performing in AEC laboratories, without charge or on a reduced charges basis to the proposers, certain mutually agreed-upon R&D work.

\footnote{For instance, sometimes Shippingport is included and sometimes it is not.}
3. Making payment, to be fixed in advance, for technical and economic information resulting from the project. This information would then be made available by the AEC to the technical public working on reactor development [3, p. 4].

Four proposals (presented later) were received in response to this invitation. The Dresden reactor, which only sought a construction permit, was among these proposals.

The second round invitation, issued in September 1955, was of interest principally to public and cooperatively owned utilities. This invitation sought proposals for small utility type plants. The cooperation offered originally was AEC financing and ownership of the nuclear steam supply system, performance of necessary R&D, and waiver of fuel use charges. The ground rules for these type arrangements were clarified by Congressional action of the AEC's Fiscal Year 1958 authorizing legislation. These rules included separate contracting by the AEC for reactor design, fabrication and construction, AEC financing of reactor operation and maintenance costs, utility purchase of steam delivered, and utility option to buy the reactor portion of the plant upon completion of the contract term. Seven proposals were received, and two plants were constructed. There are indications that this round was the result of Congressional pressure for public ownership of nuclear power facilities [31, p. 39].

A third round invitation was issued in January 1957. This invitation required only that the plants proposed make a significant contribution toward the achievement of commercial nuclear power. In addition to R&D assistance and fuel use charge waivers, certain types of plants could also obtain free use of heavy water during the first five years of plant operation. Five proposals were received, and two plants were built [31, pp. 39, 40].

In August 1962, the AEC issued an invitation known as the "modified third round," which sought to encourage industrial construction and operation of large nuclear power plants (400 Mwe or more) using "proven reactor concepts." The contractual arrangements provided AEC financial assistance up to a maximum dollar amount which was used for architect-
engineering design for the complete plant (excluding vendor's design). Where design assistance was supported, the AEC was to own the designs, and they could be made available to others as the Commission saw fit. Charges for special nuclear materials and heavy water could also be waived. As in a third round arrangement, the utility was responsible for plant construction and operation and had title to the entire facility. Two proposals were received, and both resulted in contracts, but only one plant was constructed [31, p. 40].

Other elements of the PDRP were assistance to unsolicited proposals, specifically invited projects, and to proposals for advanced converters (the second phase of the program).
II. CHANGING UNCERTAINTY: THE YANKEE PLANT

Yankee Atomic Electric Company (Yankee Atomic) was one of four proposers to respond to the AEC's first round invitation. These four were Power Reactor Development Company (Detroit Edison and Associates), Commonwealth Edison, Consumers Public Power (Nebraska), and Yankee Atomic. Commonwealth Edison only sought permission to build, but the other three proposers sought to participate in cooperative ventures with the AEC. Yankee Atomic first submitted its proposal in March 1955 and revised it in August 1955. Yankee Atomic's proposal was the last of the four accepted by the AEC as the basis for negotiation. Included in the Yankee Atomic revisions was an increase in the net electrical output [4, p. 47].

In evaluating the proposals, the AEC considered the following factors:

1. The probable contribution of the proposed project toward achieving economically competitive power.
2. The cost to the AEC in funds and materials.
3. The risk to be assumed by the proposer.
4. The competence and responsibility of the proposal maker.
5. The assurances given by the proposed against abandonment of the project [2, p. xii].

Although the Yankee Atomic proposal was the last accepted for negotiation, the first contract of the PDRP's first round was awarded to Yankee Atomic in June 1956 [16 p. 60]. This contract provided for the construction and operation of a pressurized light water-cooled and moderated reactor (PWR) and plant capable of producing at least 134 Mwe. Figure 2.1 presents a simple flow diagram of a PWR power plant. The AEC agreed to waive inventory charges for the first five years of operation (cost estimate: $3.3 million), to support up to $4 million of private R&D and to do up to $1 million of R&D in its own laboratories [31, p. 39].
INITIAL IDEA

The high cost of energy in New England attracted New England utilities to the concept of nuclear power for electricity generation. On the day after President Eisenhower signed the amended Atomic Energy Act, August 31, 1954, ten New England utilities agreed to form the Yankee Atomic Electric Company. These utilities were New England Electric System, Connecticut Light and Power Company, Boston Edison Company, Central Maine Power Company, Hartford Electric Light Company, Western Massachusetts Electric Company, Public Service Company of New Hampshire, Eastern Utilities Associates, New England Gas and Electric Association, and Central Vermont Public Service Corporation [6, no page]. The development of an interest in nuclear power plants has been attributed to the leadership of the president of the New England Electric System. He knew President Eisenhower, served on several government panels, and, unlike some leaders in the utility industry, did not fear government involvement in the development of nuclear power generation technology. He considered the development of the technology to use nuclear power to be important to the United States and especially important to the New England region, which lacked indigenous energy sources.
PROJECT GOALS AND TARGET AUDIENCE

The Reactor Development Division of the AEC wanted the Yankee project to demonstrate what operability, reliability, and economics could be achieved with nuclear power plants. The PDRP was designed to encourage utility and manufacturer learning because the AEC viewed learning as an important part of the commercialization process. The interest of the Joint Committee on Atomic Energy in seeing civilian reactors built was also an element in the entire PDRP.

Yankee was clearly to be one of several demonstration projects with the federal government supporting those in the private sector willing to take risks by trying various approaches to nuclear power production. There was also an element of the AEC and JCAE developing confidence in the feasibility of civilian nuclear power.

The general feeling at the time was that nuclear power would benefit the nation, and that the government should help the private sector in developing promising approaches for providing that power.

TECHNOLOGICAL UNCERTAINTY

A nuclear power plant is viewed here as consisting of a nuclear side and a conventional side. The technological uncertainty varies for each of these components and also for the design, construction, and operation of each component.

The "heart" of the Yankee plant and its nuclear steam supply system is its reactor. This reactor is a pressurized light-water-cooled-and-moderated reactor (PWR). The reactor heats water in a closed-cycle system to about 529°F under 2,000-psig which then generates the steam used for the electricity generator in a heat exchanger type steam generator.

---

1The description here of the utilities and manufacturers as the "target audience" is a distinction used in describing the PDRP for the analytical purpose of this study. It should not be interpreted as meaning that a conscious a priori decision was made by the AEC or the JCAE to "target" these groups. There are also indications that the AEC and JCAE themselves learned from the demonstrations.

2A schematic drawing of such a system is presented in Figure 2.2.
Fig. 2.2—Schematic of current reactor coolant system for PWR\(^a\)

Source: USAEC, "Reactor Safety Study," WASH 1400, Draft, August 1974, Figure 3.3, p. 57.

The current systems do not have stop valves, which are present in the Yankee reactor [24].

Pre-Project Uncertainty

The reactor's major components are the core, the controls, the coolant, and the moderator. The PWR type was chosen by Yankee Atomic because "technologically this type was well established" [16, p. 59]. Although the technology was established, the uncertainty issue was complicated by the classified status of much of the information. Yankee's
reactor was the scale-up of a developed concept, namely a PWR, but it had new features. These new features included uniformly-enriched uranium-oxide fuel, stainless steel cladding for the core [16, p. 59], an in-core instrumentation system for monitoring power generation and the use of a boric acid solution in the reactor coolant during cold shutdowns to suppress reactivity [18, p. 53].

Although the feasibility of the PWR concept was considered known, the need to make power production economical required substantial technical changes, of both a quantitative and qualitative nature.

The naval program, which employed PWRs to provide submarine propulsion, is generally viewed as having provided "tremendous confidence" in the PWR technology. This program included the dual-purpose plant at Shippingport, which was used for naval work and for electric power generation.

Although Yankee was not larger than its contemporary conventional plants, it was a large plant in terms of its use of saturated steam. Saturated steam was the only possible steam output from the PWR, and, therefore, a new turbine design was required. This new design included steam blades for the last stage which were longer than for any other turbine generator using saturated steam.

The containment sphere for Yankee, illustrated in Figure 2.3, was wholly above-ground and elevated. This was a novel concept, but the technological uncertainties involved do not appear to have been great.

There does not appear to have been any concern about the storage of nuclear wastes. Such civilian wastes would have been a relatively minor concern given the comparative amount of military waste at the time.

**Addressing Technological Uncertainty**

The technological uncertainty affected Yankee Atomic's planning for the project by influencing the R&D and personnel program, as well as contractor and technology selection.

---

1 It was also larger than any conventional plant in New England at the time.
Fig. 2.3—Elevation View of Yankee Plant

Source: Ref. 28, p. 51.

R&D Planning. Before actual plant engineering and design was authorized by Yankee Atomic, an R&D contract was negotiated with Westinghouse. The R&D was directed towards:

- $\text{UO}_2$ pelletization methods,
- stainless steel cladding-tube closures,
- ways to join fuel rods into bundles using brazed ferrules and straps,
- optimized core design,
- analyses of control-rod and chemical-poison effectiveness,
- plant safety, shielding, steady-state and kinetic performance,
- planning and analyses of critical experiments,
- corrosion
tests of reactor-system materials, development of water-chemistry techniques and of a water-soluble neutron absorber, mechanical design of the fuel assembly, core supports, control rods and latch-type magnetic-jack drives (tests of loading, reliability, life), fuel-handling devices, critical experiments and irradiation tests (including in-pile loops), thermal and hydraulic design of the reactor system, development of Ag-In-Cd control rod with diffusion-bonded nickel-plated cladding, assistance with startup experiments [16, p. 60].

**Personnel Planning.** The technological uncertainties of PWR technology required the organizations involved in the Yankee project to provide specialized training for their personnel.

The New England utilities, especially New England Electric System (NEES), began preparing for its first use of nuclear energy in 1950, years before the legislation authorizing projects such as Yankee was passed. This preparation was the early initiation of nuclear engineering training for key personnel. This training began with the sending of selected persons to nuclear facilities, followed by the training of others at AEC school and then the establishment of Yankee's own school.¹

Several of the Westinghouse key personnel had nuclear experience in the nuclear submarine program, especially at the Bettis Laboratory Westinghouse operated in support of its submarine work.

**Selection of Technology.** The PWR selected by Yankee Atomic was not the first reactor concept considered. Previous to the formation of Yankee Atomic, NEES had work under way with a nuclear group at Monsanto and with the Fluor Co. in Los Angeles. The original concept under consideration by NEES was also a PWR, but of a type described as "entirely different."

Yankee Atomic's first proposal to the AEC for funding through the PDRP was for an 80 Mw plant based on the Monsanto-Flour design. This was soon revised to a 100 Mw plant. The Monsanto-Flour design was judged by the AEC to have limited future potential. Originally, the design called for the use of Thorium fuel. This was changed to slightly enriched uranium

¹The details of this training program are presented in Ref. 21.
with aluminum cladding. Such cladding would have been temperature limited, and the resultant steam temperatures would have been so low that thermal efficiencies of only about 25 percent were estimated as possible.¹

Meanwhile, Stone and Webster (S&W), a Boston architect-engineer firm, went to Westinghouse and suggested that they submit a joint proposal using the pressurized water reactor (PWR) concept developed by Westinghouse. Westinghouse had started trying to convince Yankee Atomic to change to a Westinghouse-supplied plant even before the AEC's rejection of Yankee Atomic's original proposal.

The first Westinghouse design used elements developed from their submarine reactor experience. It called for highly enriched uranium fuel, which meant a high fuel cost. Westinghouse modified the fuel to slightly enriched uranium, but at that time, the uncertainty was so great that some were not even sure such fuel could be produced.

The reactor chosen for Yankee was a closed-cycle, pressurized light-water reactor designed for normal operation at 2000-psig closed-system pressure and 514° F average coolant temperature. The closed-cycle reactor was selected as superior in 1955 on the basis of five factors:

1. Operating history.
2. Estimated economics.
3. Inherent stability and safety.
4. Reasonable efficiency and unit size.
5. Well enough established technology to commence engineering and construction immediately [28, p. 49].

Contractor Selection and Background. As suggested above, at this time, the selection of a technology limited the selection of the reactor supplier (and vice versa) because each reactor manufacturer was developing a markedly different approach of his own. For instance, Westinghouse had a particular type PWR, General Electric had a particular type

¹Today, nuclear plants attain thermal efficiencies of about 32 percent.
BWR, and so forth. When Yankee Atomic was making its decision, Westinghouse Electric Corporation was building the Shippingport plant for the government. They also had a contract to build a small commercial reactor in Belgium, the BR-III (Ref. 9).

Stone and Webster Engineering Corporation (S&W) was the architect-engineer (A-E) to Westinghouse at Shippingport. S&W first became associated with nuclear work during World War II when they were the original prime contractors for Project Manhattan, and later they were involved at Oak Ridge National Laboratory. S&W was selected by Westinghouse to do the A-E work at Shippingport after S&W won a competition for the subcontract.

As mentioned above, S&W, an A-E firm based in Boston, brought New England Electric's interest in a nuclear plant to the attention of Westinghouse.

Operating with Technological Uncertainty

The Yankee project's operation should be considered as having at least three phases. During the first phase, the basic R&D work was done and the plant was designed. The design choices influenced the R&D, and the R&D results influenced the design. During the second phase, the Yankee plant was constructed and the licenses required for operation were obtained. The third phase is the actual operation of Yankee as a power plant.

R&D and Design. As mentioned earlier, Yankee Atomic was assured of an R&D effort by Westinghouse and AEC laboratories to address problems they anticipated would require solution for Yankee. Many of the features investigated were incorporated into the design of Yankee. This R&D work is viewed as having had a major effect on core design.

Westinghouse operated fairly independently during the R&D phase. Yankee Atomic had a resident engineer at Westinghouse, but Westinghouse engineers did not feel there was any significant interference from either Yankee Atomic or the AEC. When the R&D cost more than the $5 million estimated originally, $5.3 million, the AEC quizzed the contractors heavily about this overrun. Yankee Atomic paid the additional costs, explaining to the AEC that the original R&D cost estimate had necessarily been made very crudely.
The three contractors met regularly with the AEC's representatives in the Schenectady, New York regional office and with persons from the Division of Reactor Development in Washington, D.C. This project "evolved," and the AEC people were involved at a working level. The three contractors even were able to present alternative solutions at informal working sessions with AEC persons present, and the AEC persons had workloads that allowed them to get involved in working out solutions.

Yankee Atomic had to authorize Westinghouse and S&W to proceed with the designs for the specific nuclear plant to be built in Rowe, Massachusetts. However, when Westinghouse presented the proposal to build a plant for Yankee Atomic, Westinghouse already had done a good deal of design work. Nevertheless, Yankee Atomic appears to have influenced certain aspects of Yankee's design. All three partners, Westinghouse, S&W, and Yankee Atomic, made important contributions to the design process.

The novelty of the civilian nuclear power industry and the high degree of competence of the Yankee Atomic technical and managerial personnel helped Yankee Atomic play a significant role in the Yankee project. The influence of Yankee Atomic appears to have generated a balance of influence among the three parties (Westinghouse, S&W, and Yankee Atomic), where normally the utility would have played a minor role in such an undertaking.

Changes in the original design were initiated by Westinghouse. For instance, Westinghouse convinced Yankee Atomic of the merits of its proposal to use vertical steam generators at Yankee. Vertical steam generators of the size required for Yankee had not been built before, but they had been used on submarines. Horizontal steam generators had been used at Shippingport. Yankee Atomic was concerned about natural circulation during shutdown with vertical steam generators, but after they were tested and natural circulation demonstrated, Yankee Atomic agreed. The use of vertical steam generators has become standard practice.

Fairly late in the planning process, Yankee Atomic with AEC encouragement decided to include in-core instrumentation in its design. This instrumentation provided readouts in the control room and a profile of the flux distribution in the core.
These decisions, as most of the inter-contractor decisions for Yankee, were made on the basis of the technical merits of the positions presented. Persons involved in Yankee's development have stated that most influence from the AEC came from the Regulatory Branch rather than the Reactor Development Division that was handling the financial assistance.

Plant Construction and Licensing. There were no technological obstacles to plant construction or licensing. The use of an entirely above grade containment sphere simplified installation of equipment, but it had negative effects for later operations [16, p. 61]. Even though special safety features were included, S&W was able to build the plant on schedule by designing and constructing Yankee like "any other power plant."

Power Plant Operation. Yankee Atomic was responsible for operation of the Yankee plant. It was standard Westinghouse practice to sell its equipment to the operators. Yankee Atomic operated the Yankee plant so as to learn about the routine commercial operation of a nuclear power station. Therefore, the operation strategy was to hold research and development programs to a minimum [16, p. 61].

Plant Startup. The first Yankee core was loaded in such a manner that, in retrospect, equipment problems that could have been uncovered were not noticed. Both the fuel-handling cavities and the fuel chute were dry at the time of the new and non-radioactive Core I's loading. This oversight led to the discovery of problems during a wet and radioactive refueling instead of during the initial fueling, which could have been wet and non-radioactive [10, pp. 64, 65].

The Yankee reactor went critical on August 19, 1960 after a smooth two-hour approach according to plan. The only unexpected observance during this procedure was that the core was slightly more reactive than anticipated. This meant that the fuel rods could supply more energy than previously estimated. After criticality was attained, the reactor was operated to familiarize and train personnel. During this period, some short circuiting of the control-rod operating coils was caused by the borated water, but this was corrected.
In September 1960, data collection at low reactor temperatures began. This data was required to calculate control-rod and boron reactivity worths. Next, temperature, pressure, and flow coefficients of reactivity were measured at various temperatures, and control-rod and boron worth were measured at operating temperatures. Most of the bothersome troubles with these low power tests were non-nuclear, i.e., mechanical.  

On July 29, 1960, Yankee was issued a provisional license by the AEC for power generation up to 392 Mw, i.e., 110 Mwe (net). Yankee first produced power and fed it into the New England grid on November 10, 1960. A four step sequence taking four or five weeks was planned to bring the reactor up to the licensed power rating, but turbine troubles developed when 70-90 Mwe were being generated [16, pp. 60, 61]. Because Yankee was a very large saturated steam plant, a new turbine design had been required. A vibration problem that developed was solved by the two rings' supporting the first eight stages of reaction blading being removed and slotted to provide space for the steam to flow. In mid-January 1961, Yankee was brought to its full licensed power.  

The next step was a 500 hour data gathering run required for the licensing procedures. This run encountered only three minor interruptions [16, pp. 60, 61].  

Routine Operation. Yankee plant operation was much more successful than expected. This was still a pioneering venture, and the Yankee technical team had to solve some difficult problems. Excluding time lost for refueling, the conventional side of Yankee was the major source of lost time. This is illustrated by the reactor availability factors for the first four years presented in Table 2.1.  

The major source of lost time due to the nuclear side of the plant was refueling, which occurred once a year. In fact, refueling was the major drag on plant load factors in general [10, p. 64]. Through the experience gained from several refuelings at Yankee, the Yankee team

---

1These difficulties are detailed in Ref. 16, pp. 60, 61.
2120 Mwe gross, 110 Mwe net.
became confident that they knew what needed to be done for design in and about the reactor vessel, the type of refueling equipment needed for annually refueled reactors, and the normal refueling outages that should be required for the closed-cycle reactor. The Yankee team reduced the time required for refueling from 4 months the first time to 35 days the third time [10, p. 64].

The significantly improved refueling operations at Yankee were viewed in early 1965 as holding great promise for the nuclear power industry. In particular, Yankee Atomic fed information back to its contractors so that the lessons learned at Yankee could be incorporated into the design of Connecticut Yankee. With the advantage of this information, Yankee Atomic was projecting Connecticut Yankee refueling times of three weeks or less [10, p. 64].

Yankee's performance in 1965 (the last year of the demonstration funding) was not as outstanding. This outage was primarily due to examination and modification of reactor internals initiated because of problems discovered at Consumers Power Company's Big Rock nuclear power plant [29, pp. 42-46].

Destructive core testing was possible with Yankee's fuel rods because of the demonstration nature of the plant. Westinghouse proposed this testing, and it was executed by Westinghouse with AEC funding. Such testing could not have been performed without Yankee Atomic's cooperation because it owned the fuel until after fuel reprocessing, at which point most of the information about the condition of the core would have been lost. The destructive testing of the Yankee core helped
improve the AEC predictions of the reactor fissionable material inventories and increased its confidence in vendor predictions of reactor parameters. It helped Westinghouse design better reactors. It also benefited Yankee Atomic because the tests confirmed Westinghouse's prediction of the plutonium content, and, therefore, the AEC paid Yankee for the plutonium before the core was reprocessed [17, p. 2].

A more detailed description of the technical problems which arose at Yankee and their solutions is presented in References 10 and 29.

Uncertainty Reduction

Although the potential adopters did not perceive the PWR approach as involving great technological uncertainty, a great deal of technological information about commercial PWRs was developed at Yankee.

Some of the problems encountered and solved were:

- Turbine problems.
- Refueling problems.
- Fuel rod ratcheting.

The Yankee project's R&D led to major advances in the state of the art of core design for PWRs, and the release of the spent fuel rods to the AEC before reprocessing for destructive testing also added a great deal of knowledge about the core and the conservatism of its design. Yankee also pioneered the use of a boron shim during commercial operation. Westinghouse had been developing boron shim in its Saxton reactor and made the results of chemistry, reactivity, and safety tests available for the Yankee project. Boron shim is now standard in Westinghouse reactors [17, p. 3].

As a consumer of reactors, Yankee Atomic saw the production of publicly available information as being in their own long term interests. The enlightened attitude was strongly influenced by Yankee Atomic's management, and led to the publication of many topical reports, technical papers, and operating reports. The steady commercial operation of the plant also generated confidence in the reliability of the technology.

Thus, the general confidence in PWR technology was based on much firmer ground as a result of Yankee.
COST UNCERTAINTY

Yankee Atomic's major goal for Yankee was to operate it in such a way as to learn about routine commercial operation [16, p. 61]. Thus, cost information was planned to be the major product at Yankee, and it was produced with the bonus of unexpectedly reduced costs.

Pre-Project Uncertainty

Although the technical feasibility of producing power with PWR technology had been demonstrated at Shippingport and other reactors, no usable cost information existed from these projects. Cost estimates for Shippingport were described as ranging from 50 to 100 mills per kwh, according to what factors were included in the cost calculations. The earlier PWR work had military goals, and industry felt there was a significant difference between the economics appropriate to a military project, and the economics appropriate to the utility industry.

The early, post-construction, estimates for the 136 Mwe output were from 15 to 11 mills/kwh. This was broken down as 8-10 mills/kwh in capital costs and 3-5 mills/kwh for fuel and operation. Improvements in fuel cost and performance were expected to bring the cost of nuclear power nearer to the 9 mills/kwh typical in 1961 for New England [16, p. 59].

The capital costs for Yankee were estimated at $57 million in 1957. However, the final capital cost was approximately $40 million. Thus, we might interpret the first estimate to have been fairly uncertain.

The cost information which the utility industry management wanted to know about was (a) how much would a plant cost, (b) what were the operating costs, and (c) how long would it take to get one running.

Addressing Cost Uncertainty

The uncertainty about the costs involved in the Yankee project had to be considered by the AEC, the contractors and the institutions financing the project.

AEC. The AEC addressed the issue of cost uncertainty by closing the end of its commitment. Its R&D funding was limited to a maximum of $5 million, and its waiver of fuel use charges was limited to five years. The AEC helped while the risks were assumed privately.
Contractors. The New England utilities formed Yankee Atomic to pool their risk capital to meet the capital requirements for a commercial nuclear plant and to share the risks and benefits. Presumably, the formation of a separate company limited their risks also.

Yankee Atomic did not think this first nuclear plant had any chance of being economically competitive, and, therefore, it had sought PDRP funding from the AEC to decrease the project's cost to Yankee Atomic.

The three parties to the contract with the AEC agreed to share the risks of any cost overruns or underruns. Nevertheless, each party felt that the original cost estimates were conservative. A cost-plus-fixed-fee type contract, rather than the turnkey type popular for the early nuclear plant projects, was used [13, p. 1]. The risks were shared for the first increment of overrun, and after that, Yankee Atomic had to cover additional overruns.

Financiers. Because of the early state of the art and the idea that no one really knew if the plant would work or not, the Security and Exchange Commission (SEC) allowed Yankee Atomic to sell its bonds and do its other financing by private placement. The sale of $17 million worth of bonds was arranged in a private placement to a group of insurance companies. Arrangements were made for another $15 million to be raised by bank loans.

The Yankee Atomic has been characterized as a "shell" before the Yankee plant was built. The corporation had no assets except for the promise of the sponsor utilities to buy the electricity produced by the Yankee plant. Because of this uncertainty, the financiers sought a guarantee from the sponsoring companies of the principal and interest on the bonds. However, the sponsor utilities refused to even talk about such a guarantee. The major uncertainty as far as the financiers were concerned was whether the Federal Power Commission would allow Yankee Atomic to recover all its costs in the power rate charged the sponsoring companies for the electricity supplied to them. A research agreement was developed to diminish this uncertainty. Through this agreement, sponsor utilities would cover any potential difference between the total costs incurred by Yankee Atomic and the costs the FPC might allow to be included in the power rate.
Operating with Cost Uncertainty

Again, it is useful to look at operation of the Yankee project in terms of three phases, R&D and design, plant construction and licensing, and power plant operation.

R&D and Design. To produce less expensive power that could become commercially attractive for the generation of electricity, R&D work was done on the core, fuel, and steam production of PWR technology. These economically-generated changes produced a plant that has been described as quite different from previous PWRs. For instance, using stainless steel cladding for cost reasons generated several R&D tasks.

Plant Construction and Licensing. Delays in completion of nuclear power plant projects can affect project costs significantly because of interest costs and the relatively rapid inflation of field labor and other related costs. Yankee Atomic did not anticipate any construction delays, and there were none. Compared to later nuclear projects, the lack of public concern and/or delay might be viewed as amazing, but at the time, the country's attitude toward nuclear power was more benign. This is discussed in more detail when examining institutional and externality uncertainty.

Power Plant Operation. As mentioned earlier, the operational strategy at Yankee was to minimize R&D activity so as to maximize commercial operating experience [13, p. 1].

The instrumentation added to the core relatively late in the project generated advantages that far outweighed the disadvantage of complicating refueling. The instrumentation gave Yankee Atomic and the AEC information about the performance of the core. This data availability was responsible for the very early and substantial power increases allowed at Yankee. The data helped convince the AEC that power levels could be increased safely. These increased power levels helped to significantly decrease the per unit cost of electricity from Yankee.

Uncertainty Reduction

The Yankee project proceeded from a flimsy base of cost information to develop a sound foundation upon which commercial judgments could be made concerning the PWR.
Confidence in the ability to design a commercially feasible nuclear power plant was generated. This confidence was based on the successful completion of the Yankee plant below cost estimates and ahead of schedule, and on the performance of the core designed to produce lower priced nuclear power. Reliability is also a very important economic factor to a utility when selecting the technology for a new large power station. This should be considered in the cost discussion because the newest plants supply the base load and any outage means that more expensive sources of power (either older plants or grid purchases) must replace it. Yankee generated confidence in PWR commercial reliability.

The development of confidence on the part of utilities in the technology demonstrated at Yankee extended to the financial community. The relative ease with which financing was arranged for subsequent projects is described later.

DEMAND UNCERTAINTY

Since the electricity produced by a nuclear power plant is indistinguishable from the electricity produced by any other power plant, there was no demand uncertainty associated with the Yankee project.

INSTITUTIONAL UNCERTAINTY

The Yankee project was not directed towards affecting any uncertainty related to institutional factors, but, inevitably, the project's organization and operation shed some light on these matters.

Pre-Project Uncertainty

The elaborate personnel training program associated with the Yankee project [21, pp. 47-49] is evidence that there was concern about the supply of manpower able to operate a nuclear power station. However, there is no evidence that there was uncertainty about the outcome of this program given the participation of key personnel. No evidence has been found to indicate any significant uncertainty with respect to possible labor problems resulting from the new responsibilities and potential hazards associated with nuclear power.¹

¹Apparently, the idea of premium pay for nuclear plant operators was raised "in union circles," but nothing ever came of it.
Since the Atomic Energy Act gave the AEC jurisdiction over matters dealing with radiological hazards, important changes in relations with state health or environmental agencies were not a problem. Nor does there appear to have been concern about the possibility of AEC refusal to grant permits for the construction and operation of Yankee.

The formation of the multi-utility Yankee Atomic Electric Company presented the major perceived institutional uncertainty that had to be addressed by the Yankee project.

There was another element of uncertainty related to the potential institutional effects of the introduction of nuclear power production. This was concern about the possibility of federal ownership of all nuclear facilities. There is debate about whether or not there was any real chance of such federal control developing, but there is no question about the perception of this threat by many private utilities at the time the first nuclear power plants were conceived. In the mid-1950s, Senator Gore of Tennessee, a member of the JCAE, had introduced a bill which would have promoted federal ownership, and this probably played an important part in these fears.

Addressing Institutional Uncertainty

The Yankee Atomic organization had two important tools for dealing with any institutional uncertainty it encountered, the prevailing general optimism towards technological solutions to problems and the leadership of its management.

Post-World War II optimism appears to have been an important factor during the formative stages of the Yankee project. This optimism extended to the new source of energy. When this influence was coupled with the limited resources available to each New England utility and New England Electric's leadership, the normally individualistic New England utilities were able to agree on doing a joint project.

Operating with Institutional Uncertainty

Internal Organization. Yankee Atomic was a new organization, but if it is viewed as a utility, the Yankee project probably involved top management more than any conventional plant would have at that time.

The utilities dealt with unions they considered responsible. They were less powerful than some unions, and they also acted in what were
considered the best interests of the industry. This labor behavior was characterized as being typical in healthy industries.

Federal Assistance. Some utilities avoided federal funding for their nuclear power projects because they were concerned with the role of private enterprise and/or fear that this federal intervention would ultimately expand to federal ownership. Yankee Atomic was not prepared to assume all the risks involved with the project and, therefore, was willing to accept federal money. Yankee Atomic's management thought that the utilities, as regulated firms, should accept any government assistance offered, and this view prevailed over any fear about government interference.

Inter-utility Agreement. Since the formation of Yankee Atomic involved the corporate finances of the sponsoring utilities, there were some problems with regulatory agencies. Such problems had to be worked out with the Security and Exchange Commission, the Federal Power Commission and state regulatory commissions. The shares of the sponsoring utilities are presented in Table 2.2

Table 2.2

<table>
<thead>
<tr>
<th>Utility</th>
<th>Percent Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England Power Company(^a)</td>
<td>30.0</td>
</tr>
<tr>
<td>Connecticut Light &amp; Power Company</td>
<td>15.0</td>
</tr>
<tr>
<td>Boston Edison Company</td>
<td>9.5</td>
</tr>
<tr>
<td>Central Maine Power Company</td>
<td>9.5</td>
</tr>
<tr>
<td>Hartford Electric Light Company</td>
<td>9.0</td>
</tr>
<tr>
<td>Western Massachusetts Electric Company</td>
<td>7.0</td>
</tr>
<tr>
<td>Public Service Corporation of New Hampshire</td>
<td>7.0</td>
</tr>
<tr>
<td>Montauk Electric Company(^b)</td>
<td>4.5</td>
</tr>
<tr>
<td>New Bedford Gas and Edison Light</td>
<td></td>
</tr>
<tr>
<td>Company(^c)</td>
<td>2.5</td>
</tr>
<tr>
<td>Cambridge Electric Light Company(^c)</td>
<td>2.0</td>
</tr>
<tr>
<td>Central Vermont Public Service</td>
<td></td>
</tr>
<tr>
<td>Corporation</td>
<td>3.5</td>
</tr>
<tr>
<td>Connecticut Power Company</td>
<td>0.5</td>
</tr>
</tbody>
</table>

\(^a\)Subsidiary of New England Electric System.
\(^b\)Subsidiary of Eastern Utilities Associates.
\(^c\)Subsidiaries of New England Gas and Electric Association.

\(^*\)Source: Reference 6.
Licensing Procedures. The location chosen for the Yankee plant minimized the likelihood of public concern or protest about it. The Deerfield River had a total of eight hydroelectric generating plants and no towns downstream of Yankee used water pumped directly from the main stream of the river for domestic purposes [6, no page]. Thus, this potential problem was avoided more than solved. The population of Rowe, Massachusetts was about 250, and the town has been characterized as having the lowest tax rates (because of taxes paid by Yankee) and best schools and roads of any town in Massachusetts. Yankee was one of the contributors to these taxes, but the New England Power Company’s Sherman hydroelectric station was also adjacent to the Yankee site [6, no page]. Thus, Rowe probably tended to maintain good relations with the utilities. These factors coupled with an extensive Yankee Atomic public information program, helped prevent any construction delays caused by public protest, a common construction problem on later projects. A threat of intervention during the Yankee licensing proceedings had been mentioned, but it never materialized.

The AEC licensing procedure, still in its formative stages, was handled on an ad hoc basis for Yankee. While there was a question about how the process would work, there were no major hangups. Since the regulatory process had not yet become institutionalized, it was relatively easy to get things taken care of, especially with Yankee Atomic’s management always ready and able to help cut the red tape.

Nevertheless, there were some snags with AEC regulation, such as with AEC operators licenses. AEC operators licenses were required for certain nuclear plant personnel. Through talks with the AEC, Yankee Atomic came to understand that the Yankee engineers could qualify to take the license exam prior to startup and fuel loading by working on the test reactor at MIT. About a week before the test was scheduled to occur, Yankee Atomic received a letter from the AEC stating that none of the five persons whose names had been submitted were qualified to take the test. Personal intervention by Yankee Atomic management was required before the persons could take the test.
Institutional Constraint

When considering the behavior of the utilities which formed Yankee Atomic, and those which were watching the Yankee project, it is useful to understand the constraint on investments with which they were operating.

Before a utility can put up money for a large scale new venture, it must know about its cost, its technical feasibility, and when a return on the investment can be expected. This has been described as especially important to a utility because of the conservatism of its stockholders. Thus, the risk-taking behavior of a utility must differ significantly from that of, say, a chemical company.

Institutional Uncertainty Reduction

Through the Yankee Atomic experience, the New England utilities became convinced of the usefulness of working together. In addition to nuclear projects, this cooperation extended to the creation of the New England Power Pool that provides a power grid and includes group planning, dispatching, and financing services. For the nuclear plants, the technical expertise developed for and by Yankee was held as a common inheritance by the cooperating New England utilities.

Internally, the importance of upper level management involvement was not discerned at the time; however, Yankee Atomic had displayed a sensitivity to this need.

Yankee's success has been said to have given the Joint Committee confidence that the PDRP was working, and to have generated confidence there about the use of nuclear power in a utility system.

The licensing process was not institutionalized at the time of Yankee, and the ad hoc procedure used could not be generalized. The procedure required preliminary and final "Hazards Summary Reports," and public hearings were held [24]. Nevertheless, the lack of major regulatory obstacles probably encouraged utilities to expect the AEC to be relatively cooperative in approving nuclear projects. However, the licensing process increased in difficulty over time because of the growth of formality and of public opposition.

Finally, to the extent that Yankee decreased the risks associated with nuclear power, it decreased the significance of the constraint
imposed upon utilities by the risk-aversive preferences of their stockholders.

UNCERTAINTY ABOUT EXTERNALITIES

This dimension of uncertainty deals with possible good or bad effects which might be imposed upon persons or institutions other than those directly involved with the technological innovation.

Pre-Project Uncertainty

At the time the Yankee project was being formed, nuclear plants were seen as an alternative to improve environmental conditions. Californian utilities were said to have been particularly anxious to develop nuclear power for this reason because they were often blamed for smog and did not want to continue being dependent on one source of clean energy, Canadian natural gas. In New England, coal was used and using coal was a dirty, miserable process involving the movement of large volumes of input coal and of waste ash. Since there was no concern about the routine emissions of minute amounts of radioactivity, nuclear power was considered a means of decreasing air pollution.

No major concern on the part of potential adopters or the public about the possibility of a nuclear accident nor of the damage that thermal pollution could cause to aquatic life has been uncovered. The regulatory branch of the AEC was concerned about nuclear safety, but approval of Yankee is evidence that they were sure there would be no serious accident.

Although Yankee Atomic did not expect a nuclear accident, it was not prepared to carry the burden of all the risk involved with a nuclear plant. The lack of information about the probabilities and potential consequences of an accident made it impossible to get sufficient liability insurance for the operation of a nuclear plant. Yankee Atomic would not have built a nuclear plant without the Price-Anderson Act. (In brief, the government provided insurance and limited its own liability to $500 million through this Act.) This hesitancy on the part of the utilities was not unanimous; the Consolidated Edison Company of New York said it would build its Indian Point plant without the passage of the Price-
Anderson Act. Nevertheless, the insurance industry's refusal to provide coverage indicates the significant uncertainty about the chances and magnitudes of any possible accidents at a nuclear plant.

Addressing Uncertainty About Externalities

The regulatory persons at the AEC followed the design and construction of Yankee closely. Their influence is indicated by their affecting Yankee's design at least as much as the Reactor Development Division, which had provided the federal funds.

Instrumentation was placed in the Deerfield River upstream and downstream from the Yankee plant to monitor the effects of Yankee's operation on the river water's temperature. This instrumentation was in addition to the in-core instrumentation desired by the AEC and Yankee Atomic to monitor the core's performance.

The lack of experience in the use of nuclear power also led to the use of a very conservative approach in the design of Yankee. For instance, Westinghouse had originally designed the reactor to guarantee 134 Mwe. Later, the core was shortened one foot after Yankee Atomic agreed that Westinghouse was not required to guarantee the 134 Mwe but would try to achieve it. Subsequently, reactor power output was increased from 392 Mw to 600 Mw, based on in-core instrumentation measurements of hot channel factors and by the use of boron shim, which had not been proven when the Yankee core was first designed. The early high hot channel factor calculations were based on the worst possible combinations of reactor core parameters. [17, p. 3].

Operating with Uncertainty About Externalities

At each stage of licensing (construction permit, provisional operating license, etc.), the AEC convinced itself of the safety of the Yankee plant.¹ Since Yankee Atomic's short term goal was the production of power as economically as possible, the AEC watched design changes to assure themselves that such changes did not sacrifice what it considered

¹See AEC, Docket No. 50-29.
system safety for economic reasons. For example, stainless steel cladding for the fuel elements was less expensive than Zircalloy cladding, but stainless steel cladding did not have the operational history that Zircalloy cladding had. Research on stainless steel cladding was proposed in the original Westinghouse R&D agenda for Yankee [17, pp. 3, 4]. When the AEC was convinced of the safety of stainless steel, it approved its use.

The plant first attained criticality on August 19, 1960 after a smooth two-hour approach. Low power and full power (110 Mwe net) tests were also required by the AEC [16, pp. 60, 61]. As late as 1965, start-of-life physics testing was still performed on a new core [29, p. 42].

Radioactive contamination problems occurred during the first refueling (see Ref. 16), and working areas had radiation levels above design values, but extra shielding was devised for the workers entering the contaminated zones [16, pp. 65, 66]. By the third refueling, the Yankee team had reduced the total average radiation exposure to personnel during refueling from about 3 rads per man for the first refueling to about 0.7 rads per man [16, p. 64]. There was never any serious leakage to the external environment.

Yankee's location near a hydroplant meant that careful records were kept of the river's flow near Yankee. This data, combined with the temperature readings from the monitoring equipment in the river provided information about the Yankee plant's contribution to thermal pollution. However, concern about the possibility of thermal pollution in the early stages of Yankee appears to have prevented the development of generalizable information about the thermal effects of a nuclear power plant on a river. Yankee was designed to take water from deep in the Sherman hydroplant's reservoir and return it to the reservoir's surface after using it for cooling. Because the water at the bottom of the reservoir was much cooler than the surface water, it was even possible for the water downstream of Yankee to be cooler when Yankee was operating than when it was not.

**Uncertainty Reduction**

The radiation exposure to plant personnel was decreased significantly during the early years of Yankee's operation. However, there never was major concern about such radiation.
The data collected on the thermal effects on the Deerfield plant operation were important. However, it does not appear that the results were considered applicable to other plants because the use of the hydro-plant's reservoir for the cooling water made Yankee an unusual case.

Although insurance carriers began to supply some insurance coverage, utilities still required Price-Anderson protection after Yankee's first years of operation. This indicates that there was still substantial uncertainty about the chances and magnitudes of possible nuclear accidents, even given the experience of Yankee and other reactors.

TERMINATION OF DEMONSTRATION FUNDING

From the very beginning, Yankee Atomic planned for Yankee to be a power producing plant and intended to run the plant as much and as continuously as possible. Also, given the economics of electrical power generation, once the plant had been built and the construction costs had become sunk costs, it made sense to keep the plant operational. Upon funding termination, Yankee was kept in operation.

INFLUENCE OF FEDERAL SUPPORT

The relatively minor federal assistance to the Yankee project made a major contribution to the development of PWR technology because it was just enough assistance to change a "maybe" decision to a "yes." However, the parallel efforts that were funded entirely from private sources suggest that some utility or group of utilities might have built a reactor equivalent to Yankee without federal support. It seems unlikely that the project would have been as successful without the Yankee Atomic team.

AFTERMATH

The Yankee plant became the model upon which later PWRs were based. The Westinghouse line of reactors evolved from Yankee, and Combustion Engineering and B&W, two other PWR producers, have also used information developed at Yankee, together with Indian Point and Shippingport information. Westinghouse even tried to sell a scale-up of Yankee for a guaranteed price before Yankee began producing electricity [33, p. 17].

In March 1964, Yankee was placed under international safeguards by the United States. In taking this action, the government sought to
demonstrate that international safeguards were feasible and could be carried out without infringing on national sovereignty. In November 1964, the first international inspection of a large nuclear power station by a team of reactor inspectors from the International Atomic Energy Agency took place at Yankee [25, p. 62].

The second round of the AEC's PDRP was directed towards the relatively small, cooperative and publicly owned utilities. The small size of the reactors required for these systems did not prove to be commercially feasible because of the significant economies of scale associated with the generation of electricity from nuclear power.
III. CHANGING UNCERTAINTY: THE CONNECTICUT YANKEE PLANT

Connecticut Yankee Atomic Power Company (CY Atomic) was one of two proposers to respond to the PDRP "modified third round" invitation issued by the AEC on August 23, 1962. Plans for the plant were announced publicly in December 1962 [5, p. 2]. The construction permit for the Connecticut Yankee plant was issued in May 1964. This plant was to provide 463 Mwe (net) of electricity with a PWR power source [7, p. 2], and is illustrated in Figure 3.1.

The other respondent to the AEC's modified third round invitation was the Los Angeles Department of Water and Power. Engineering requirements imposed by the earthquake potential for the proposed site of the Malibu plant caused very long procedural delays. In February 1970, the AEC terminated the agreement because the delays had eliminated the possibility of the plant's contribution to the civilian power reactor program [31, p. 40].

In several ways, the Connecticut Yankee venture was a direct extension of the Yankee project. The owner was Connecticut Yankee Atomic Power Company, which was patterned after Yankee Atomic. The design and construction of Connecticut Yankee were under the general supervision of the man who held the same position for Yankee. The two principal contractors for Connecticut Yankee were the same as for Yankee, Westinghouse Electric and Stone and Webster [7, pp. 2, 26, 27].

INITIAL IDEA

As might be expected, the idea for construction of a nuclear power plant in Connecticut originated with the Connecticut utilities. Two Connecticut utilities and Western Massachusetts Electric formed the Nutmeg State Electric Co. in early 1962. Nutmeg retained S&W to evaluate BWRs and PWRs for a possible nuclear plant in Connecticut.

After the AEC had presented its invitation for the modified third round of the PDRP to assist in the provision of nuclear power plants

1 This plant is also known as the Haddam plant.
with at least 400 Mw capacity, Nutmeg began to prepare a proposal. During the preliminary negotiations, Yankee Atomic people were involved to a limited extent. It has been reported that while Nutmeg was getting ready to submit its proposal, a meeting of Yankee Atomic's board of directors took place in Hartford, Connecticut, and a report on the Nutmeg project was presented. Several of the directors, who were executives of the companies sponsoring Yankee, questioned the idea of the Connecticut utilities proceeding on their own and suggested that the utilities all get together again and follow the model of cooperation used for Yankee. Before the end of the meeting and without much discussion, a decision had been made to form the Connecticut Yankee Atomic Power Company.

Twelve utilities were stockholders of CY Atomic. These utilities were Connecticut Light and Power Co., New England Power Co., Boston

PROJECT GOALS AND TARGET AUDIENCE

Encouraged by the operating experience of such nuclear plants as Shippingport, Dresden and Yankee, the AEC perceived a need to scale up the size of nuclear power plants. The invitation for proposals for a modified third round of the PDRP was issued to encourage industrial construction and operation of plants with capacities greater than 400 Mwe (net). More specifically, the invitation's objective was "the demonstration of the design, construction, and operation of large all-nuclear power plants as reliable sources of electric power under base load conditions" with "proven concept" reactors [31, p. 40]. Since Connecticut Yankee was the only plant constructed as a result of this round, it is reasonable to consider this to be the AEC's goal for the Connecticut Yankee plant.

CY Atomic participated in the PDRP because it was seeking as economical a source of power as possible, and AEC funding lowered CY Atomic's costs.

The target for Connecticut Yankee was more focused than for earlier projects because the AEC, JCAE, and manufacturers were convinced of the commercial feasibility of nuclear power. The project was aimed at generating more utility enthusiasm for nuclear power.

TECHNOLOGICAL UNCERTAINTY

Although the Connecticut Yankee adopted many features from Yankee, it also incorporated design innovations based on the Yankee experience [32, p. 91]. The major advancements for PWR technology in Connecticut Yankee were related to the control system and containment design.

Pre-Project Uncertainty

The invitation under which Connecticut Yankee received AEC funds
called for plants using proven reactor concepts, and, therefore, Connecticut Yankee relied heavily on the technology proven with Yankee.

There were some novel technological ideas tried first at Connecticut Yankee. These included engineered safeguards, computerized data collection, more efficient fuel handling equipment, improved control rod drives, and shaft-sealed main coolant pumps. Also, the structures were the first in New England to be designed to meet earthquake criteria [32, p. 94].

Addressing Technological Uncertainty

CY Atomic followed a strategy that minimized the uncertainty it would be required to address for technological reasons. This influenced personnel planning and the technology and contractor selection.

Personnel Planning. Apparently underestimating the accomplishment of the Yankee technical team, Nutmeg began planning its nuclear project without developing nuclear expertise in its technical staff. However, since Nutmeg never got beyond the very early stages of making a proposal and getting ready to contract, no significant problems developed because of this lack of expertise. Any outside technical assistance required in the early stages was supplied by S&W. When the decision was made to form CY Atomic, the key personnel on the Yankee technical team were shifted to the Connecticut Yankee project. (After this shift took place, the Yankee team still kept an eye on the operation of the original Yankee plant.)

Selection of Technology and Contractors. The Nutmeg utilities were interested in building a nuclear plant and the decision appears to have been whether to build a BWR or a PWR, with other reactor concepts eliminated from consideration from the very beginning. They felt that both of these technologies had been shown to be viable through the success of the respective prototype plants (Dresden for BWR, Yankee for PWR).

S&W had just begun its evaluation for Nutmeg when General Electric (GE) insisted that it make its evaluation alone. After this, Nutmeg instructed S&W to work with Westinghouse to develop a joint proposal. It is not clear why GE elected to push S&W back into an affiliation with Westinghouse, thus reuniting the team which had built the "Nuclear
Success Story of 1962" [15, p. 1]. The plant design being actively considered by Nutmeg had a capacity of between 400 and 450 Mw, which was somewhat smaller than the plant actually built.

Despite Yankee Atomic's previous association with Westinghouse, CY Atomic accepted bids for the Connecticut Yankee plant. Babcock and Wilcox (B&W), GE, and Westinghouse competed vigorously for the work. B&W's proposal to build a spectral shift-type reactor was rejected because of the economic and technical problems introduced by its use of heavy water. GE insisted on proposing a contract incorporating elements of the turnkey approach, and they also underestimated the potential for scaleup of a single cycle BWR. Westinghouse, teamed with S&W, was selected for Connecticut Yankee on the basis of a minor price advantage and willingness to build Connecticut Yankee in a manner similar to the process used so successfully at Yankee. The Connecticut Yankee technical staff considered its involvement in the design and construction of the plant to be very important in helping to develop the ability to run the plant commercially. Therefore, GE's turnkey offer was unacceptable to CY Atomic. The smooth operation of the Yankee plant probably influenced the decision as well.

Operating with Technological Uncertainty

It is useful to consider Connecticut Yankee's operation in terms of the same three phases as used for describing Yankee. These phases are (1) research, development, and design; (2) plant construction and licensing; and (3) power plant operation.

R&D and Design. Because the PWR was considered a proven reactor concept, one of the prerequisites for assistance as a modified third round demonstration, there was no direct AEC assistance for Connecticut Yankee R&D. As mentioned earlier, the major novel technological features for Connecticut Yankee included:

- Shaft-sealed main coolant pumps.
- Improved fuel handling equipment.
- Improved control rod designs.
- Computerized data collection.
- Engineered safeguards [32, pp. 91-94].
The application of some of these features were relatively straightforward, especially from the lessons of Yankee. Others required significant R&D effort before they were ready for inclusion in the plant design. The shaft-sealed coolant pumps were not in the original Westinghouse plant design but once the decision was made to use them, Westinghouse elected to develop and produce them.

Rod-cluster control was developed to replace the cruciform-rod absorber-follower assembly used previously. The new control rod consisted of cylindrical absorber elements moving in guide tubes in the fuel assembly. Rod-cluster control was expected to (1) improve the uniformity of the power distribution, (2) increase reactivity worth, (3) eliminate control rod followers without introducing penalties, (4) allow a less expensive drive mechanism, and (5) permit a shorter reactor vessel [32, p. 92]. San Onofre, a PDRP third round demonstration with Westinghouse as the reactor supplier, was planned slightly ahead of Connecticut Yankee, and cluster control and the general form of the fuel assembly was worked out for San Onofre. Although San Onofre was slightly smaller than Connecticut Yankee, the fuel assembly was very much the same, and presumably, the R&D for these features was supported by AEC assistance to the San Onofre project.

More sophisticated engineered safeguards than those employed at Yankee were required for Connecticut Yankee because of its relative proximity to a population center [7, p. 8], its larger size, and its location near an epicenter of a number of minor earthquakes [32, p. 94].

The AEC provided $6.05 million for design assistance to Connecticut Yankee. This support of Title I and II engineering gave the AEC ownership of all the plans, specifications, and drawings developed under this effort [32, p. 94].

Most of the design effort appears to have been directed towards the improvement of devices already used in other power reactors, especially at Yankee. One description of Connecticut Yankee was that everything looked just like Yankee multiplied by three. While this is an oversimplification, it does indicate the extent to which Connecticut Yankee design was based upon the Yankee precedent.

Plant Construction and Licensing. The reasons for CY Atomic's
problems during this stage of the Connecticut Yankee project were not technological; however, technical issues arose in the development of alternative solutions to the problems.

A major problem for CY Atomic was local concern about thermal pollution and its effects on the Connecticut River.\(^1\) Part of the agreement CY Atomic made in order to get a water permit for the plant was that it would take any corrective measures required for dealing with fish life problems traced to the plant. In planning for the possibility that such measures would be necessary, CY Atomic developed five corrective schemes. These alternative solutions increased in cost as the magnitude of the problem increased. The low cost scheme involved diluting the discharge water and would have cost approximately $400,000. The highest cost fix involved full scale closed-cycle cooling towers and probably would have cost four or five million dollars.

A study of the plant's effect on the river indicated that none of these corrective measures were necessary. No other technological obstacles caused serious problems for plant construction or licensing.

**Power Plant Operation.** As with Yankee, responsibility for the operation of the equipment supplied by Westinghouse was assumed by the purchaser. Thus, CY Atomic was responsible for the operation of Connecticut Yankee.

**Startup.** Connecticut Yankee first went critical on July 24, 1967, and first produced electricity on August 7, 1967 [5, p. 2].

To fulfill an additional guarantee connected with the water permit agreement, the first summer's operation was intermittent. Also, the utilities were not dependent on the power produced so that the CY technical team could keep an eye on things and be able to decrease (or shut off) power if they saw any possibility of running into trouble.

Although there had been some startup problems at San Onofre with the shaft-sealed pumps due primarily to the water filtering system, the pumps worked fine at Connecticut Yankee during startup and afterward. Trouble was averted by adopting the corrective measures developed at San Onofre before Connecticut Yankee's startup.

---

\(^1\) This problem is discussed in greater detail later in this chapter.
Routine Operation. Connecticut Yankee began commercial operation in January 1968, three months behind the original schedule date [19, p. 88]. No mention has been made of any nuclear problems at Connecticut Yankee since commercial operation began. Originally, the licensed rating for the plant was 462 Mwe net [31, p. 91]. As of February 1975, its rated capacity was 575 Mwe net [19, p. 88].

Uncertainty Reduction

Since shaft-sealed pumps that could have handled the Connecticut Yankee job existed before the project began, the pump developments associated with the project cannot be said to have reduced technological uncertainty significantly, but information about their long run performance was produced.

The major contribution of Connecticut Yankee to reduced uncertainty in the technological dimension was with the control systems. The Connecticut Yankee's capacity was planned to provide increased base load power capability for the sponsor utilities [7, p. 6]. The importance of plant reliability in supplying base load power [eg. 26, p. 7] implies confidence in Connecticut Yankee's PWR technology. However, there may still have been a need to demonstrate the reliability of PWR plants of this size because none had been sold privately at the time the Connecticut Yankee project began.

Cost Uncertainty

Yankee's performance had convinced CY Atomic that it was commercially feasible to produce electricity from nuclear power and that Connecticut Yankee would stand on its own.

Pre-Project Uncertainty

A major economic goal of the project on the part of CY Atomic was to achieve some economies of scale. To the extent that no plant as large as Connecticut Yankee had been built at the time that the decision to build it had been made, there was uncertainty connected with what the costs of the project might be. In 1965, the total capital requirements for a large Connecticut Yankee plant were estimated to be $98.5 million. Including fuel costs after the five year waiver period,
the power costs at the plant's initial rating of 462 Mwe net were estimated at 6.03 mills/kwh for operation at an 80 percent load factor. For an increased output of 562 Mwe net and operating with a 90 percent load factor, power costs of 5.13 mills/kwh were estimated. The uncertainties were related to reliability (load factor), and the efficient use of the reactor fuel's potential, which was not known precisely [32, p. 91].

Addressing Cost Uncertainty

Relatively minor cost uncertainty was associated with the Connecticut Yankee project. Nevertheless, the magnitude of the project provided an incentive for those involved in the project's finances to protect themselves by limiting, as much as possible, the extra costs that could be imposed upon them.

AEC. The AEC again pursued its policy of making a closed-ended commitment to the nuclear power plant project. The AEC contracts included the following provisions.

- The AEC would provide up to $6.05 million for design assistance, including conceptual design, and more detailed work.
- The AEC would become the owner of plans, specifications, and drawings developed under the Titles I and II effort (i.e., the design work).
- The AEC would waive fuel-use charges during the first five years of operation, up to a maximum of $7,145,000 [32, p. 94].

These contracts with Westinghouse, S&W, and Connecticut Yankee allowed the AEC to promote civilian reactor development without assuming any fiscal risks.

Contractors. The three parties signed separate contracts for the Connecticut Yankee project instead of Yankee Atomic's three-party contract signed with the two Yankee contractors and Yankee Atomic's contract with the AEC for the Yankee project. In this new arrangement, each party agreed to cover any overrun on his own part of the work. Thus each contractor shared the risks, and at the same time, cut costs
by receiving AEC assistance.

Again, contract administration was assigned to the AEC's Operations Office in Schenectady, New York. Thus, the same AEC people involved with the contract administration of the Yankee project were involved with administration of the Connecticut Yankee project [7, p. 6].

Financiers. Although the AEC was less pleased with CY Atomic's approach to financing than with Yankee Atomic's experience [7, p. 35], CY Atomic considered the financing much less difficult. As with Yankee, the level of equity funds was to cover the difference between the funding required for the project and the funds raised from other sources. CY Atomic was not allowed to make a private placement deal to sell its bonds because the SEC decided that a nuclear power plant was no longer experimental. CY Atomic was not happy with this decision. In the competitive bidding, only two syndicates bid for the $40 million worth of bonds offered. The bonds were sold at 4.5 percent. CY Atomic also arranged a $20 million loan from a Connecticut bank at 4.5 percent, which turned out to be significantly lower than the prime interest rate at the time the money was first drawn down.

Because there was sufficient confidence in the Connecticut Yankee plant, no problems about sponsor utility guarantees for the principal and interest on the bonds were experienced by CY Atomic.

Operating with Cost Uncertainty

Cost factors influenced each phase of Connecticut Yankee's operation.

R&D and Design. Connecticut Yankee's design incorporated several innovations aimed at reducing power costs through increased reliability, operability, and maintainability. Most gains were possible with simple system and component designs using "off the shelf" equipment whenever possible [32, p. 91].

Only one element in the Connecticut Yankee plant appears to have involved disagreements between CY Atomic and Westinghouse over a cost matter. This was the selection of main core coolant pumps. CY Atomic was interested in more economic pumps than the canned-motor type used at Yankee and insisted on shaft-sealed pumps. Shaft-sealed pumps were also used in the San Onofre plant, a third round PDRP nuclear plant. Since the Connecticut Yankee project provided no R&D
assistance, this development appears to have been helped by San Onofre's R&D assistance. The pump design was reviewed by a Pump Design Review Committee with members from CY Atomic, Southern California Edison, and Westinghouse. In the course of the contract, the use of shaft-sealed pumps is estimated to have saved CY Atomic about three quarters of a million dollars.

**Plant Construction and Licensing.** Cost uncertainty was introduced to the Connecticut Yankee project at this stage. Because of the large capital investments involved, delays were one possible source of significantly increased costs. The other potential cost increase was connected with the agreement to correct any effects of thermal pollution, which could have cost CY Atomic up to $5 million. The successful avoidance of these costs are more relevant to the following discussions of institutional and externality uncertainties.

**Power Plant Operation.** Connecticut Yankee's electricity generating capacity was to augment the base load capability of the sponsor utilities [7, p. 6]. The nature of base load capacity and the aim of the project to demonstrate that a large, all-nuclear electric generating facility could provide an economic source of power led to an operating philosophy emphasizing maximum power output and load factor. The inclusion of improved instrumentation at Connecticut Yankee helped raise the plant's licensed power rating.

**Uncertainty Reduction**

The Connecticut Yankee reaffirmed the claims of nuclear power's proponents that such power could be economical. It was planned on sounder economic estimates than a contemporary BWR plant funded entirely with private money, Jersey Central Power and Light Company's Oyster Creek plant.

Since Oyster Creek was funded privately and the plant's cost to the utility was significantly lower than Connecticut Yankee, it is useful to elaborate on the differences between the two plants. Jersey Central bought Oyster Creek from General Electric on a turnkey basis, which meant that Jersey Central's capital cost was fixed at $68 million [23, p. 21]. Apparently, General Electric knew it would lose money on
this particular project, but it wanted the contract to demonstrate its nuclear concept and to gain experience. Westinghouse also bid for Oyster Creek, but its cost estimate had been more realistic (and, therefore, higher), and thus, Westinghouse lost the contract. The situation that resulted at Oyster Creek has resulted in litigation and other complications. General Electric has also been described as secretive about the actual cost of the plant.

Connecticut Yankee showed that it was possible to deal with local opposition in a way that did not involve costly extended delays in plant construction. It also demonstrated that costly corrective measures were not necessary to avoid damage to aquatic life for similar size plants on similar rivers.

DEMAND UNCERTAINTY

Again, perfect substitutability is assumed for the electricity produced by all types of central power stations, and therefore, demand uncertainty is not relevant to this case.

INSTITUTIONAL UNCERTAINTY

Because the Connecticut Yankee project took place after the nuclear power issue area had had time to develop, institutions had developed positions with respect to nuclear power. Since organizations now had stakes in the outcome of the nuclear power issue, it had gained greater visibility and had come to involve more institutional obstacles.

Pre-Project Uncertainty

The Yankee experience gave CY Atomic confidence about its ability to properly manage a nuclear power project. Since the time of Yankee, however, environmental concerns had become more important in the process of issuing permits, and so, the uncertainty with respect to the approval process was probably greater than when Yankee was built.

Operating with Institutional Uncertainty

Internal Organization. CY Atomic followed Yankee’s precedent of utilizing heavy involvement of top level management. Yankee
Atomic's vice president played a similar, major role in Connecticut Yankee as he did in Yankee. Some minor labor problems arose, and some work stoppages occurred.

**Federal Assistance.** Concern about the possibility of a federal takeover of the civilian nuclear power industry seems to have dissipated by the time the Connecticut Yankee project developed. By 1962, the issue had advanced to the question of private ownership of reactor fuels [30, p. 44]. The federal assistance was accepted for Connecticut Yankee because it was offered.

**Inter-Utility Agreement.** The corporate arrangement pioneered by Yankee Atomic Electric Co. was the model for the Connecticut Yankee Atomic Power Company [7, p. 6]. Therefore, the uncertainty about regulatory problems was low. There were some new sponsoring utilities for CY Atomic and some Yankee Atomic sponsors dropped out. The difference in shares for CY Atomic reflected the different plant location. The CY Atomic shares are presented in Table 3.1.

**Table 3.1**

<table>
<thead>
<tr>
<th>Utility</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut Light and Power Co.</td>
<td>25</td>
</tr>
<tr>
<td>New England Power Co.</td>
<td>15</td>
</tr>
<tr>
<td>Boston Edison Co.</td>
<td>9.5</td>
</tr>
<tr>
<td>Hartford Electric Light Co.</td>
<td>9.5</td>
</tr>
<tr>
<td>United Illuminating Co.</td>
<td>9.5</td>
</tr>
<tr>
<td>Western Massachusetts Electric Co.</td>
<td>9.5</td>
</tr>
<tr>
<td>Central Maine Power Co.</td>
<td>6</td>
</tr>
<tr>
<td>Public Service Co. of New Hampshire</td>
<td>5</td>
</tr>
<tr>
<td>Montauk Electric Co.</td>
<td>4.5</td>
</tr>
<tr>
<td>New Bedford Gas and Edison Light Co.</td>
<td>2.5</td>
</tr>
<tr>
<td>Cambridge Electric Light Co.</td>
<td>2</td>
</tr>
<tr>
<td>Central Vermont Public Service Corp.</td>
<td>2</td>
</tr>
</tbody>
</table>


Later in the project, the local residents were stirred up and there was a threat of intervention at the operating license stage. One man who lived a couple of miles from the plant organized a number
of people in the area. This group told the AEC that they wanted to intervene. Luckily for CY Atomic, they did not follow the intervention procedures properly and never qualified as an intervenor.

Meanwhile, CY Atomic did "everything they could" to persuade the local people that Connecticut Yankee was safe. These measures included a town meeting where the unrest was centered, at which time the residents' questions were answered.

The CY Atomic organization's handling of the community relations was viewed as very skillful. Through the town meeting, the use of a "neutral" University of Connecticut team to do the environmental study, and some financial incentives, they were able to avoid the problem of having the local people out fighting the plant.

Institutional Constraint

The risks of building the Connecticut Yankee nuclear power plant appear to have been considered normal business risks, and therefore, the earlier constraint for Yankee concerning the risk preferences of utility stockholders does not appear to have been applicable to Connecticut Yankee.

Uncertainty Reduction

Uncertainty for CY Atomic and other potential adopters about institutional matters at the time of Connecticut Yankee was due primarily to local acceptance of the plant. There may have been some element of concern about AEC regulations, but the AEC still maintained a relatively bullish attitude towards the potential for civilian nuclear power. An innovation introduced with the Connecticut Yankee project was the submission by Nutmeg of a site evaluation to the AEC to obtain tentative site approval prior to the start of detailed design and licensing procedures.

CY Atomic dealt skillfully with the threat of local opposition to the nuclear plant and demonstrated that properly handled community relations could prevent such opposition from becoming a serious obstacle to project completion. CY Atomic's successful development of community acceptance encouraged the utilities of Northeast Utilities to proceed
with their Millstone nuclear power plant, which was also built in Connecticut. CY Atomic’s vice president served briefly as a consultant to Northeast Utilities during the licensing process for Millstone.

To a certain extent, the inexperience of those opposing Connecticut Yankee was a lucky break for CY Atomic. Since later projects could not depend upon the unfamiliarity of potential intervenors with AEC procedures to qualify as intervenors, the threat of such activity remained for later projects and was a source of continuing uncertainty.

**UNCERTAINTY ABOUT EXTERNALITIES**

Public concern about the effects of the nuclear plant on its environment played a much more important role on the Connecticut Yankee project than for the Yankee project.

**Pre-Project Uncertainty**

The development of public concern about the use of nuclear power did not affect the uncertainty associated with the externalities of nuclear power, but it did increase the visibility and perceptions of this uncertainty.

The potential improvement to the New England environment in terms of avoiding the pollution associated with the use of coal was still a point favoring nuclear power.

No major concern appears to have developed about the possibility of a nuclear accident even though there had been a history of minor earthquake activity in the site area. Because of specific characteristics of the Connecticut Yankee site that indicated that the river valley had a channeling effect on the prevailing breezes, extra emphasis was placed on the problem of potential radioactive emissions from the plant [7, p. 8]. The continued existence of the Price-Anderson Act can be interpreted as indicating that uncertainty still was associated with the estimation of the chances of a major nuclear accident and of the magnitude of its effects. (The Act also insured quick payment to victims of nuclear accidents.)

There was a good deal of uncertainty about how much heat energy could be discharged into the Connecticut and Salmon Rivers before aquatic life would be harmed.
Addressing Uncertainty About Externalities

Connecticut Yankee's design included four "engineered safeguards" developed by S&W:

1. Air recirculation and filtration within the containment structure using coolers supplied by river water to condense any released vapors.
2. Internal core deluge with borated water from a large storage tank, after which liquid spilled from a system break could be recovered, cooled by a river water exchanger, and recirculated.
3. Reactor containment spray with borated water from the same tank, the spray water being collected and cooled in a river-water heat exchanger and resprayed to remove additional heat and radioactivity.
4. High pressure emergency core cooling system.

The first three systems could be powered by three 400kw diesel-driven generators on site, and the fourth required normal electricity supply [32, p. 92].

All structures and systems at Connecticut Yankee that could affect public safety were designed using spectrum analysis to withstand a ground acceleration of 0.17g. This earthquake criteria applied primarily to the reactor coolant system, all safety systems, electrical supplies to critical safety components, and structures in which the equipment is housed or controlled. Connecticut Yankee's systems and structures were believed to be the first in New England designed to meet such criteria [32, p. 94].

The potential thermal pollution problem was monitored for the first five years of Connecticut Yankee's operations by a study team from the University of Connecticut [12, pp. 19–27].

Operating with Uncertainty About Externalities

The growth of the thermal pollution issue affected Connecticut Yankee operations. The Connecticut Yankee plant did not employ the cheapest possible method for using river water for cooling, which would have been to take the water directly out of the Connecticut River and
return it directly. Because CY Atomic did not want to put the hot water from the condensers right back into the river, a mile-long channel was built so that the water went down along the Connecticut River and emptied into the Salmon River near the confluence of these two rivers. By the time the cooling water entered the river, it had cooled down. CY Atomic also spent close to $1 million for the study of aquatic life. This study began during construction of the plant and continued for several years after operation began.

Uncertainty Reduction

Since the engineered safeguards designed for Connecticut Yankee were not used during the five years of the demonstration phase, the project did not provide any information about the effectiveness of these safeguards in preventing radioactive emissions.¹ The continuing need for the Price-Anderson Act also indicates the still-present uncertainty about nuclear accidents after the Connecticut Yankee demonstration.

Connecticut Yankee's greatest contribution to uncertainty reduction related to externalities probably was the thermal pollution information generated. CY Atomic had supported an elaborate study of the Connecticut River's aquatic life before and during Connecticut Yankee's operation. This study, for which the preliminary results were presented in Scientific American [12, pp. 19-27], reported on the thermal outlines of flow in the area, the ecology, and the effect of the biosphere around the plant.

TERMINATION OF DEMONSTRATION FUNDING

Several persons familiar with the project have said that the Connecticut Yankee plant probably would have been built even if there had been no federal assistance. Therefore, CY Atomic had planned from the beginning to continue the plant's operation after the demonstration phase had ended.

¹This is not meant to imply that an accident to test the safeguards would have been desirable, but to point out that no data about their performance was generated.
INFLUENCE OF FEDERAL SUPPORT

It is reasonably certain that the Connecticut Yankee project would have proceeded without federal funds. What would have been different about Connecticut Yankee if there had been no federal money is not clear. Since Westinghouse made several turnkey contracts before Connecticut Yankee was operational, starting with the Ginna plant for Rochester Gas and Electric Company in March 1965, it seems likely that Westinghouse had made a commitment to promoting its PWR with or without federal aid. The Connecticut Yankee design experience contributed to the confidence to make this decision.

AFTERMATH

Several months after the AEC negotiated the assistance for the Connecticut Yankee plant, Jersey Central and General Electric announced their contract for the Oyster Creek plant, which was to be built at a cost that could produce power more cheaply than could an equivalent coal or oil-fired plant [20, p. 26]. Even though tremendous cost overrun problems developed at Oyster Creek, it has still come to be regarded as the beginning of the second phase of civilian power reactor development [11, p. 4].

After the initial large scale nuclear power reactors (Connecticut Yankee, Oyster Creek, Nine Mile Point) were ordered, the market for such plants is said to have "stalled." By this time, the Joint Committee on Atomic Energy had decided that LWR technology had developed the base industrial load necessary for the private sector to proceed on its own. Therefore, Westinghouse and General Electric had to begin the process of selling plants with capacities in the 300 to 1,000 MWe range with turnkey contracts. This process was described as very costly to the reactor suppliers. Nevertheless, the vendors continued and today light water reactors dominate the domestic field of power reactors.
IV. OBSERVATIONS AND CONCLUSIONS

YANKEE-CONNECTICUT YANKEE COMPARISON

Yankee is the ancestor of Connecticut Yankee, and this is clear in the difference in the goals, states of uncertainty, and effects of the two plants.

Goals

Where the Yankee project aimed to provide information about the operational feasibility more than the economics possible with a PWR power reactor dedicated to commercial operation, the Connecticut Yankee project sought to demonstrate the commercial feasibility of a large PWR plant. Both projects succeeded in performing their tasks, and both are still operational. Since the fuel cost increases generated by air pollution standards and the behavior of the OPEC cartel have drastically raised the costs of fossil fuels, even Yankee has become an economic source of electricity for the New England utilities.

States of Uncertainty

Although the operational success of the Yankee plant may not indicate it, the Yankee project was very much a technologically pioneering effort. To produce power less expensively than at Shippingport, work had been done on the core, the fuel and the steam production process, and the result was a plant design quite different than for any previous plant. Although the technological and economic uncertainties were high, the informal nature of AEC regulation in the early days of civilian nuclear power, the selection of a remote site, and the prestige of the project's initiator combined to maintain a relatively low degree of institutional uncertainty for Yankee. Finally, the site selected avoided uncertainty issues concerned with thermal effects on the water body used for cooling and with effects on population centers.

Connecticut Yankee, which benefitted from the technological and economic uncertainty reduction of Yankee (and, to a lesser extent, other plants), addressed institutional and externality uncertainties in a more
direct fashion. It is not clear that this shift was a conscious decision, but it is questionable whether Yankee could have been built at the Connecticut Yankee site given the local opposition Connecticut Yankee had to overcome.

The difference in the uncertainties faced by the two plants cannot be attributed solely to the changing status of the innovation, that is, PWRs. The environment with which the projects had to interact was changing significantly. For example, the process of completing all the legal paperwork required for operation of a nuclear power plant quickly became a major task [22, pp. 81-84], but many of the regulatory matters were resolved informally for Yankee and Connecticut Yankee.

Effect on Potential Adopters

Yankee appears to have had a major influence on the attitude of private utilities towards nuclear power generation. The utilities watched Yankee closely because they were not sure that the cost for nuclear power could be brought down significantly. Even Consolidated Edison of New York, which was building its own nuclear plant with private funding at Indian Point, took advantage of technological information developed through the Yankee project. Yankee Atomic viewed expanded utility interest in nuclear power as being in the best interests of the New England utilities, and there was a conscious effort to get information into the public domain. Many topical reports, technical papers, and operating reports were published by Yankee Atomic [15, p. 1].

Connecticut Yankee does not appear to have been noticed by utilities to the same extent as Yankee. Some of this decrease in enthusiasm has been attributed to the normal loss of interest in the "second time" accomplishment of some goal. Another important factor was probably the Oyster Creek project, which got most of the publicity around the time of the Connecticut Yankee project because it was considered the first nuclear plant chosen entirely on the basis of its commercial merits. Nevertheless, Connecticut Yankee continued the line of PWR development which has been most influential.

The technical and internal organizational experience developed from these two cooperative projects was held as a common inheritance
by the cooperating New England utilities. Northeast Utilities and Boston Edison built their own nuclear plants with consultation from Yankee and Connecticut Yankee participants. The "Yankee" cooperative format was used for two more New England plants, Vermont Yankee and Maine Yankee. Also, the inter-utility cooperation continued and grew to include the creation of the New England Power Pool which provides a power grid and group planning, dispatching and financing activities.

The institutional experience from these two projects for dealing with AEC regulatory procedures was not as useful to potential adopters because of the important influence of these projects' champion and the changing regulatory environment. The institutionalization of AEC regulation led to the need for greater formality in AEC meetings with project teams, which made problem resolution more difficult, and to increasingly higher and more complex standards that had to be met by license applicants. The improved capability of nuclear foes also developed over time.

OTHER COMPARISONS

It is useful to compare Yankee and Connecticut Yankee with other nuclear projects, with other demonstrations where regulation is important, with other demonstrations in general. This can help clarify other possible lessons from these two demonstrations.

With Other Nuclear Projects

The utilities' team on the two Yankee projects has frequently been described as unusually dedicated and competent for utility personnel. This expertise, along with the expertise of the Westinghouse and S&W personnel involved with these plants, played a major role in overcoming difficulties encountered in the course of completing each project.

Although Yankee became a highly visible success, it was not always so visible. Since the AEC commitment to Yankee was relatively small, and because there was heavy AEC involvement with other concerns at the time, there were AEC people who did not even know of the project. An example of the latter phenomenon is that the invention of the BWR concept at Argonne was said to have kept Argonne's attention on the nearby
Dresden BWR plant. Also, the Bureau of the Budget reportedly did not get involved in the details of any of the demonstration power reactor projects.

The size of these two projects appears to have been more appropriate for the innovation being demonstrated than the smaller capacities of the reactors of the PDRP's second round. Although they ran, none of these smaller plants have been successful in an economic sense because they were not able to take advantage of the economies of scale necessary to make the nuclear generation of electricity commercially feasible.

The existence of "demonstration" power reactor projects that involved no federal assistance at the same time as Yankee and Connecticut Yankee confuses the identification of the influence of the federal funds on the stimulation of the technological innovation. These privately funded demonstrations appear to have occurred primarily because of a belief in private enterprise, and a fear that if the utilities did not move rapidly into nuclear power, the government would. This view has lost ground since that time, and the utilities, now more willing to accept federal aid for projects with public-good aspects, probably would not support any nuclear plants privately if they had it to do over today.

Neither Yankee nor Connecticut Yankee experienced labor problems similar to those encountered by the nuclear freighter demonstration, N. S. Savannah. Interestingly, no serious concern about the possibility of such problems ever existed for power reactors. One interviewee attributed this lack of concern to the vitality of the utility industry, which includes responsible labor organizations. He postulated that in an industry as heavily subsidized as the maritime industry, there is little incentive for labor to avoid hurting the industry, but the utility industry is characterized by both management and labor concern to maintain a healthy industry. The N. S. Savannah probably avoided the environmentally related opposition encountered by Connecticut Yankee because it was initiated before such concerns became highly salient and because thermal pollution from a nuclear reactor is not very important on the open sea.
With Demonstrations for Other Regulated Potential Adopters

The fish protein concentrate plant, demonstrated in Aberdeen, Washington, and described in another case study, is probably the clearest example of a demonstration that was severely hindered by a federal regulatory agency with jurisdiction over the project. Since the AEC was a promotional as well as regulatory federal agency, the nuclear projects did not encounter such obstacles.\(^1\)

The demonstration of homebuilding innovations, Project Breakthrough, probably had to deal with fragmented, local regulation, and knowledge of the difference in the effects of such regulation should be useful.

Although the AEC regulations were never major obstacles for Yankee or Connecticut Yankee, these regulations have been mentioned in discussions with utility executives. The assertion has been made that new regulations are often imposed on nuclear plants at a time during projects when delay would be especially costly. Thus, the new regulations were not fought. Next, the new regulations have become the standard for all later plants. This "regulatory ratchet" problem appears to have become an important source of concern on the part of potential adopters of nuclear power. Similar evidence with other regulated industries would be useful.

LESSONS FOR DEMONSTRATIONS

There are many lessons to be learned from the Yankee and Connecticut Yankee experiences. The major lessons for demonstration project implementation are the importance of risk-sharing, of private sector initiative, of regulatory flexibility, and of early R&D experience for the personnel involved.

Risk-Sharing

The AEC made a closed-ended commitment to each of the demonstrations examined in this paper. This means that the AEC provided assistance without accepting any of the risks involved with the projects. For these

\(^1\)It will be interesting to see what happens in the nuclear field now that the regulatory and promotional functions have been separated.
two demonstrations, the risks were shared among the utility plant operator, the nuclear steam system supplier, and the Architect-Engineer. This risk-sharing gave each participant a stake in providing accurate (or at least conservative) a priori cost estimates and in minimizing the costs of the project.

To some extent, the AEC also geared its assistance to the areas of greatest risk. For instance, the R&D assistance for Yankee covered almost all of the R&D required at a point in PWR development when the substantial technological uncertainty called for R&D activity. Assistance for Connecticut Yankee supported the design effort, which included the design of the engineered safeguards required at Connecticut Yankee because of its proximity to population centers and a minor earthquake area. Both projects also received in-kind assistance in the form of five years of fuel use charge waivers. It has been suggested that this was important because the amount of nuclear fuel inventory that would be required was not well known.

**Private-Sector Initiative**

The philosophy employed by both the JCAE and the AEC toward federal assistance in the early stages of the implementation of civilian power reactor technology was that these funds should support any technology that private industry was willing to back. The federal government did not make the decisions about which technologies would be given demonstration money, although some proposals were rejected. Rather, private industry selected the technologies on which it was willing to accept the risks, and the AEC gave each selection a limited subsidy.\(^1\)

The AEC approach allowed the private sector to take the initiative in the development of civilian power reactor technology. Each reactor vendor advanced reactor concepts it viewed as most promising, and each utility chose the best offer made to it by a vendor (or vendor, Architect-Engineer team). Only after this stage of negotiations had been completed was the agreement for federal assistance finalized. Thus, options remained open for different paths of reactor development, the normal

---

\(^1\) This is not entirely true for the second round of the PDRP, in which public utilities got power reactors.
relationships between vendors and buyers was maintained, and the private sector had to decide if it wanted power reactors rather than to decide if it would build them for the government.

**Regulatory Flexibility**

The ability of the management of these two projects to deal with the bureaucracy through formal and informal channels made an important contribution towards the successful completion of the plants. The funding agency must judge whether the benefits to the project from making arrangements for cutting red tape outweigh the costs in terms of the perception of the project as a special case, not relevant to institutional questions about regulation, by potential adopters.

**R&D Experience of Personnel**

The importance of expertise in the personnel responsible for a demonstration was especially evident with the Yankee project. The personal familiarity with nuclear power of many of the Westinghouse, S&W, and Yankee Atomic engineers made it possible for the project to deal with high technological uncertainty. The quick and effective responses to the problems that arose allowed Yankee to be operated on a commercial basis in spite of its "pioneer" status.

**Other Lessons**

These projects also point out the importance of the proper scaling of a demonstration in its success. Choosing the proper scale involves evaluating the tradeoff between the importance of reliability and the importance of reducing any uncertainty related to large-scale operation. Yankee often relied upon the testing of technical changes on the Westinghouse pilot-scale research reactor. This suggests that in some cases it may be possible to demonstrate, on a relatively large scale, an innovation that still involves high technological uncertainty if proper technical support on a scaled-down version of the device is arranged.

The early reception Connecticut Yankee received indicates that Yankee might have had considerably rougher going if the less remote site had been chosen. This cannot be stated with certainty, however, because
of the changing nature of public opinion during the time between Yankee and Connecticut Yankee.

There appears to have been little hesitancy on the part of reactor suppliers to avoid projects involving federal funds.\(^1\) Such hesitancy was described in the case of the Freeport saline water conversion demonstration and was attributed to the federal policy making the patents developed on such work public property. When this lack of concern about nuclear patent ownership was brought up, respondents explained that the relatively large importance of experience and of the development of mutual trust between the supplier and utility for nuclear projects made patent considerations much less important for nuclear work.

**IMPLICATIONS FOR THE RAND ETIP STUDY**

Whether or not the federal funds made a difference in the outcomes of these projects, there is no question that they were well-run demonstration projects. Therefore, the following points are important to Rand's assessment of demonstration projects:

- If the federal funding did not make a major difference in the ultimate outcomes for PWR technology, it did speed up the process.
- The sharing of risks by the three parties involved in implementation of the demonstration provided incentives for accurate cost estimation and for minimal extra project costs.
- The requirement for the private sector to take the initiative allowed the leaders among the potential adopters and suppliers to make their own choices about what particular technology they wanted to back and to maintain pre-existing relationships because the reactor suppliers had previously supplied other generating equipment.
- The flexibility of the regulatory process was a factor in the success of these two projects.
- The previous experience of the technical personnel with research reactors for Yankee (and with Yankee for Connecticut Yankee)

\(^1\) Although GE did not participate in any PDRP projects, there are indications that it tried hard to get the Connecticut Yankee contract.
played an important part in solving technical problems which arose at the demonstrations.

- There is still a great deal of uncertainty facing potential adopters of nuclear power reactors, but this is "new uncertainty" arising from changing regulations and rising public opposition to nuclear power by persons familiar with the legal requirements for intervention in the regulatory process.

Finally, the JCAE decided to end support of LWR development because an industrial base had been formed and there was pressure from competitors of LWR supplies to end the subsidies, and not because the uncertainties had been reduced. This was a result of the many LWR projects in the PDRF and not just the two projects examined here. Thus, Yankee and Connecticut Yankee were important elements in a larger program that helped develop a system capable of delivering and improving LWR technology on its own, with federal intervention continuing in the form of fuel enrichment and reprocessing and of Price-Anderson Act subsidies for liability coverage.
REFERENCES


REFUSE FIRING DEMONSTRATION
(SOLID WASTE-TO-FUEL CONVERSION)

by

Edward W. Merrow
CONTENTS

Section
I. INTRODUCTION ...................................................... J-1
   Funding ......................................................... J-6
   EPA Evaluation Activities ................................. J-7

II. UNCERTAINTIES ................................................... J-8
   Technological Uncertainty ............................... J-9
   Cost Uncertainty ........................................... J-13
   Demand Uncertainty ...................................... J-16
   Institutional Uncertainty ............................... J-19
   Uncertainty About Externalities .................. J-24

III. DISSEMINATION AND DIFFUSION ................................. J-27
   EPA Activities ............................................. J-27

IV. CONCLUSION ...................................................... J-31
    Possible Lessons for Federal Policy ................. J-32

Appendix
A. SOLID WASTE DISPOSAL ACT ............................... J-37
B. ALTERNATIVE TECHNOLOGIES--OFFICE OF SOLID WASTE
   MANAGEMENT PROGRAMS .................................. J-45
C. SCALING TECHNOLOGICAL UNCERTAINTY ................ J-47
D. EPA'S RFD DISSEMINATION PAMPHLET .................... J-51

BIBLIOGRAPHY ...................................................... J-55
I. INTRODUCTION

This is a case study of a project which demonstrated for the first time that it is technically and economically feasible to recover a substantial amount of energy from the nation's solid waste for use as fuel for existing boilers. Until this demonstration began operating in 1972 in St. Louis, Missouri, the only energy recovery from waste taking place in this country was the use of waste heat from incineration, usually to make steam. Such systems are generally inefficient both economically and in terms of energy recovery. The St. Louis system, on the other hand, promises to be efficient in both respects.

The system consists of two major steps. First, the solid waste must be prepared for use as a fuel. This consists of mechanical shredding, followed by a separation process which removes most of the inorganic (non-burnable) material. The product of this step is a well-homogenized almost completely organic material. The second part of the process consists of pneumatically firing the material into a utility boiler in conjunction with a pulverized coal. (Details of the technology and its problems can be found on J-9 to J-13 below.) The St. Louis Refuse Firing Demonstration (RFD) was the first and simplest of a number of alternative technologies to recover energy from waste. These other technologies are also being demonstrated or evaluated by the Energy Recovery Program of the United States Environmental Protection Agency.*

The remainder of this section consists of a discussion of the major actors in the RFD, their organizational settings, and the background history of the innovation's development.

There were four organizational principals in this demonstration. The Horner-Shifrin Company is a consulting engineering firm in St. Louis. It was with an executive of Horner-Shifrin that the idea for the RFD originated. Horner-Shifrin was deeply involved in the demonstration project throughout, first in developing the concept, and then in designing the system for the RFD. Horner-Shifrin had a long history in solid waste problems before the

*Energy Recovery Program, Resource Recovery Division, Office of Solid Waste Management Programs, Environmental Protection Agency.
RFD. The second principal was the Union Electric Power Company of St. Louis. Union Electric is a privately owned utility which supplies power to eastern Missouri and nearby counties of Illinois and Iowa. Union Electric was involved in the very preliminary development of the idea with Horner-Shifrin and became the user of the fuel from the city's plant. The third principal is the government of the City of St. Louis. The City owned and operated the refuse processing plant and was the conduit for all federal monies. The Refuse Department and especially its head, Wayne Sutterfield, was one of the moving forces behind the innovation from the beginning. The fourth principal was the Federal Government. Three federal agencies were involved in funding the demonstration. Initially, the Bureau of Solid Waste Management (DHEW) funded a feasibility study and then was joined by the National Air Pollution Control Administration in funding the demonstration facilities. In October 1970, the Environmental Protection Agency was created and the federal responsibility for the RFD was transferred to EPA's Office of Solid Waste Management Programs. Staff and funds were also transferred.

The basic concept for the RFD originated in 1967, with a vice-president of the Horner-Shifrin Company, Vance Lischer. Horner-Shifrin had for many years been active in designing incinerators as one of its many activities in mechanical engineering design. In addition, Mr. Lischer had a strong personal interest in environmental protection. At a professional meeting, contact was made with an engineer from Union Electric, John Bryan.

The core idea was quite simple: given that a great majority of municipal refuse is organic (c. 80 percent) and therefore combustible, it should be possible to prepare the waste as fuel. If it were burned only as a supplement to coal in large boilers, then perhaps no major changes in boiler technology would be necessary. Early in the discussions Wayne Sutterfield, St. Louis Refuse Commissioner, was contacted and was very receptive to the idea. It was then decided to submit a proposal to the Bureau of Solid Waste Management (DHEW) to conduct a feasibility study. The response from BSWM was immediate and favorable. Fifty-thousand dollars was awarded to the City which in turn contracted with Horner-Shifrin to conduct the study. Thus within a year of the idea's inception, the four major organizational actors in what was to become the demonstration project had already begun to commit themselves and cooperate in developing the idea. In important respects, the foundations were already laid for the future success of the RFD.
The BSWM's enthusiasm for the idea can be traced not only to the merits of the proposal, but to the fact that the sponsoring of the proposed technology was in complete accord with the Bureau's mandate under the Solid Waste Disposal Act of 1965. The Act explicitly cited the need to "promote the demonstration, construction and application of solid waste management and resource recovery systems which preserve and enhance the quality of air, water, and land resources." The Act provided for support of all phases of the development of new technologies.*

Several points are important to note. The individuals involved in this project were all in positions in their organizations to have some influence on decision-making. They were all within easy physical distance of one another and the representatives of the three organizations worked together in the development of the idea from its inception. Furthermore, the three organizations taken together included every step in the process. The city would collect and process the solid waste; Union Electric would consume it; Horner-Shifrin would supply technical assistance to both. This kind of cooperation and participation typically results in a good deal of personal commitment to the success of an undertaking. In addition, the successful development of the technological innovation offered possible benefits to the three organizations.

For Horner-Shifrin, the prospects of being the developer of a major new technique of solid waste disposal offered the possibility of future profits as designers of such systems. As mentioned before, the firm was already in this market, and was aware of the pressing need for technologies to replace incineration and landfill, both of which were increasing in cost. Environmental issues were becoming important at this time, and landfill and incineration both pose pollution problems. The possibility of developing the idea with federal money was appealing, because it reduced the risk to Horner-Shifrin. The patent incentive to develop the idea without public money was not thought to exist. Because the technology was expected to be so simple and the components off the shelf, Horner-Shifrin presumed that the idea would not be patentable. Horner-Shifrin was to "lose" about one hundred thousand dollars in the development of the RFD over the next three years, but the early judgment that such losses would turn out to be profitable investments is being borne out.

*Sec 202b, see Appendix A page J-37 below.
The incentives for Union Electric were also relatively straightforward. First, the idea was perceived to have some substantial public relations value, which Union Electric officials deemed important. Perhaps more importantly, the idea offered some prospects of economic benefits. The solid waste fuel might serve to solve coal supply problems. In addition solid waste fuel is very low in sulphur (lower than low-sulphur coal) and might offer the possibility of easing pollution problems. Finally, there was the possibility that burning solid waste fuel would be cheaper per BTU than the low-sulphur coal they were burning. * There are two other possible benefits to Union Electric, but we were unable to verify whether or not they were perceived as a possibility in the initial period: (1) it is possible that any boiler burning solid waste will be subject to less stringent air quality standards than conventional utility boilers and (2) there is a good chance that capital investment in solid waste processing facilities by Union Electric can be raised with tax exempt bonds, which of course significantly lowers the price of money. The first issue will be discussed later in conjunction with Union Electric's present plans for greatly expanded facilities. **

Despite the fact that Union Electric was very enthusiastic about developing the RDF concept, the company made clear from the beginning that it wished to have no contractual arrangements whatsoever with the federal government. All of the research conducted by Union Electric was funded by the company, even though federal funds might have been available. Later, when the demonstration project was funded, Union Electric again funded all of its own development. The only reason adduced by our contacts was that the president of Union Electric is ideologically opposed to government intervention in business activities. Union Electric has maintained the "private enterprise position" throughout and emphasized it in its press releases.

*Missouri regulation of utilities prevents Union Electric from making a profit on lower costs of fuel. Increases and decreases in fuel costs are completely passed on to users automatically. As will be explained below, Union Electric has found a way to circumvent this problem by using a wholly-owned subsidiary, the Union Colliery Company, as the official buyer and seller of solid waste fuel. Union Colliery is outside the purview of the regulatory agency, and therefore not legally limited in its profit margin.

**Several of our contacts suggested that Union Electric's interest in the demonstration project per se waned substantially after the basic process was proved. The reason for this is that most of the uncertainty reduction took place in the early stages of the project. Having obtained this information, UE then concentrated its efforts on its own commercialization of the system.
(Possible advantages to the company of noninvolvement with government will be discussed later.)

The incentives for the City of St. Louis to become involved in the development of refuse as a fuel were perhaps even more compelling than for Horner-Shifrin or Union Electric. Since about 1950, St. Louis has been undergoing one of the most dramatic declines of any of the nation's troubled core cities. Since peaking at close to 900,000 in the early 1950's, St. Louis' population has declined steadily to about 560,000 in 1975. The minority population has jumped dramatically; the percentage of high-income families has declined sharply; industry is moving, along with the middle class, to the suburbs.* The result is a sharply reduced tax base combined with a population requiring greater public expenditures. Thus, when Horner-Shifrin and Union Electric approached the City with an idea that might save money, they struck a responsive chord.

Horner-Shifrin, Union Electric, and the City Refuse Department all had reputations as innovative organizations before the RFD was conceived.**

It is noteworthy that there was some amount of risk involved for all three parties especially in the absence of federal government intervention via funding. The federal share of the cost was $2,580,000, with Union Electric investment of $950,000 and St. Louis' contribution of 358,000 making up the required local share of the cost. (The federal government spent another $1 million for air pollution and other evaluation.) It is unlikely that the idea would have been developed in the absence of federal funds in light of the necessity for the City of St. Louis' cooperation. Given the City's financial squeeze, it is very unlikely that it would have been willing to put up much more money than it in fact did.

The federal government's role in this demonstration project was largely confined to funding the project from the R & D stage through completion of the demonstration, aiding in the evaluation (especially of pollution questions) and dissemination of the results. All three of these roles appear to have been performed effectively. No federal agency had any direct role in the development of the idea or in the execution of the demonstration itself.


** The fact that the Refuse Department was an innovative organization is perhaps somewhat surprising in light of retrenchment due to budget cutbacks. When one considers the speed and severity of the City's decline, the willingness to innovate is more understandable. The organizational costs of change were going to be imposed by the uncontrollable forces of migration whether or not innovative risks are taken.
FUNDING

The original funding resulted from an unsolicited proposal from the city of St. Louis which had been developed in conjunction with Horner-Shifrin and Union Electric to the Bureau of Solid Waste Management, DHEW. The proposal requested $50,000 to conduct a feasibility study. BSWM responded within weeks, funding the proposal for the full amount. The feasibility report was issued in the Spring of 1970. At the same time, the City submitted a proposal to contract a demonstration plant to process solid waste for use in one of Union Electric's coal fired boilers. The BSWM was very favorably impressed by the proposal and wished to see it funded, but had already obligated its demonstration funds for the fiscal year. In an unusual move, BSWM then requested the National Air Pollution Control Administration's assistance in funding the demonstration project. NAPCA reviewed the feasibility study and agreed to put up close to half of the federal money to get the demonstration project started. The funding arrangements, as required by the Solid Waste Disposal Act, were for the federal government to supply two-thirds of the money, with the remaining one-third coming from other sources. Much of the local third was made up of Union Electric's costs in modifying its boilers and building storage facilities. This money was counted toward the local third despite the fact that Union Electric had no contractual dealings or obligations with the federal government. Apparently, Union Electric did not even know that its investment would be included in the local share until after the fact.

The demonstration was formally initiated on July 1, 1970. Soon thereafter (October) the Environmental Protection Agency was created by Congress. The BSWM and its programs were transferred to the new agency along with funds and staff. The project was now funded out of the Office of Solid Waste Management Programs. The reorganization reportedly had very little disruptive impact on the demonstration project. This was true for several reasons:

*The fact that the idea for the RFD originated with the demonstration performers was important for this case. As we proceed with our Phase II cases, it will be interesting to see if there is a consistent relationship between demonstration outcomes and the degree to which the proposal was developed without government involvement. Our conjecture is that proposals originating outside of government may be more effective in addressing pressing user needs.
The level of federal involvement was high only with respect to funding. Therefore, nothing operational would be affected by a reorganization as long as the money kept flowing in.

Soon after EPA was created, Congress passed the Resource Recovery Act which amended the Solid Waste Disposal Act of 1965 to provide $220 million for demonstration projects involving resource recovery. Thus, the availability of full funding was virtually assured.

EPA's Office of Solid Waste Management Programs was interested in keeping the RFD going for the same reason BSWM had been keen to fund it to begin with; they perceived that they had a winner, a winner that would show tangible results in a relatively short period of time.

**EPA Evaluation Activities**

EPA's second major role in the RFD was to encourage and contract for evaluation of the demonstration project. The Resource Recovery Division of OSWMP contracted with MITRE to develop a framework for evaluating resource recovery systems. The final report was issued in November 1972.* Using MITRE's framework as a guide, EPA contracted with the Midwest Research Institute in 1973 to conduct a market study of the St. Louis system, and a system evaluation. Battelle was hired to conduct air pollution tests at the Union Electric boiler, and MITRE was hired to evaluate the air classifier. In addition, the Air Programs Division of EPA conducted independent tests of air pollution. Thus, EPA was heavily involved in gaining as much information from the St. Louis demonstration as possible. This evaluation activity, however, had relatively little impact on the actual operations of the RFD.

The third major role of EPA, the dissemination of the results of the RFD, will be discussed later in this Note.

*MITRE's evaluation framework bears some striking resemblances to our conceptual framework for the demonstration study, especially in viewing the reduction of sets of uncertainties as the most important role of demonstration projects.
II. UNCERTAINTIES

At the outset of the RFD, uncertainties existed in all of the five dimensions described in the conceptual framework for the ETIP study: technological, cost, demand, institutional, and with regard to externalities.*

It is significant, however, that although uncertainty existed in each of the dimensions, it can only be characterized as moderate in most. Several factors contributed to the moderate levels of pre-project uncertainty.

(1) The City, Horner-Shifrin, and Union Electric made careful preparations and plans for the demonstration before the request for funds was made. Our Horner-Shifrin contact who was intimately involved in the planning described their orientation to the problem as the "negative approach." The question they asked repeatedly was, "What can go wrong?" Their assumption seems to have been that Murphy's law would apply. Thus, although they were all taking some amount of risk by their involvement with the idea's development, they were taking the risks very cautiously. As a result, virtually all of the operational difficulties which subsequently arose with the RFD were anticipated in the early stages of planning.

(2) The preparation for the demonstration was conducted by people who were uniquely qualified to do it. Horner-Shifrin (as mentioned above) had been in the waste disposal design field for 15 years and therefore knew not only the technology but the market. Refuse Commissioner Sutterfield ran a highly efficient department.** The engineers at Union Electric not only knew boiler technology, but had been in the forefront in installing the

---

*For a detailed discussion of the conceptual framework, see Walter Baer, Leland Johnson, and Edward Merrow, Analysis of Federally Funded Demonstration Projects: Final Report, The Rand Corporation, R-1926-DOC, April 1976. In the case of the RFD, the only uncertainties which are germane are those in the minds of the actors in the demonstration. Pre-project uncertainty about the technology on the part of potential adopters (i.e., municipalities and utilities) is not relevant because the idea originated with the RFD. The basic notion of the conceptual framework that the levels of pre-project uncertainty are important determinants of the success of the demonstration holds nonetheless.

**Sutterfield instituted a route assignment system in St. Louis which is atypical of municipal sanitation departments. Collection teams are assigned routes of about equal length and difficulty. When they have finished their
most modern pollution control equipment. (Later on during the demonstration, the UE engineers conducted their own air pollution tests.)

(3) The Horner-Shifrin feasibility study not only substantially reduced the technological uncertainty surrounding the subsequent demonstration, but provided grounds to believe that the technology would be within a competitive range in terms of cost. Cost uncertainty remained quite high, nonetheless. As in all phases of the research, development and demonstration of the technology all three of the principal organizations were involved during the feasibility study.

TECHNOLOGICAL UNCERTAINTY

The aspect of the technology which was stressed by all of our contacts is its utter simplicity.* The basic components at the processing plant consist of (1) a hammermill, such as is used to grind up junked automobiles, (2) a magnetic belt to pull ferrous metal out of the refuse, and (3) a cyclone separator which separates the lighter, generally burnable, fraction of the refuse from the heavier fraction. (See Figure 1.) All of the components of the processing plant were off-the-shelf items being put to a new use. The original processing plant did not include the cyclone separator (called an "air classifier"). To no one's real surprise, they found that without the air classifier, the resulting fuel contained particles which were not only unburnable but were jamming the pneumatic feeds at the boiler.

route they are free to leave for the day, with the proviso that if they miss anything, they have to return for it. Some teams finish as quickly as five hours after they start, others take more than an eight-hour day. The result of this practice (which is typical of private companies) has been a cost/ton of refuse collected which rivals highly mechanized collection systems.

*The RFD technology is the simplest of any of the resource recovery technologies currently being demonstrated or evaluated by EPA. (See Appendix B for descriptions of the other technologies.) Our contact at Horner-Shifrin notes that "better" technologies for producing solid waste fuel and other recoverable items from municipal waste have become available. In his opinion these technologies may be too sophisticated to work reliably. (Reliability is quite important for solid waste disposal systems; a city continues to generate garbage whether or not the facilities to process it are operating.) Technologies which make other kinds of fuel from waste, e.g., gasification and liquefaction, are much more sophisticated technologically, but result in a product which is more flexible in its use than solid waste fuel.
In terms of the amount of technological change required, all of the components of the system had been used at the same scale, but required a new integration for the RFD.*

The technology at the Union Electric Company was even simpler than the processing facilities. (See Figure 2.) The blowers and feeders to move the solid waste fuel were of the same type used to move coal. Coal has many of the same qualities as solid waste fuel; it's abrasive and contains a significant amount of non-burnable material that forms ash in the furnace. Thus the problems of handling the fuel were basically familiar to the power company. The one exception was the necessity for a surge bin to assure an even supply of the solid waste fuel. A number of modifications were necessary before an adequate surge bin system was worked out. Again this problem was basically one of construction, not "high technology."

The most fundamental technological uncertainty in the minds of the City and Union Electric was simply whether or not solid waste fuel would burn adequately in conjunction with coal. They were not sure that the refuse fuel would burn fast enough in suspension to provide much in the way of heat. The difference of a fraction of a second in burning time would be very important to whether or not the fuel would be usable. Solid waste fuel has a fairly high ash content even when burned completely (or nearly so). If burning was not nearly complete, the ash problem would be unmanageable. They did not know how high a percentage of solid waste could be burned efficiently with coal. In addition, it was not known with certainty what effects (if any) the burning of solid waste would have on the boiler itself, and in particular whether or not heavy slag deposits would form on the walls of the boiler. The reduction of these uncertainties was absolutely necessary to the adoption of this system by others, and a demonstration scale project was necessary to reduce these uncertainties. This last point was emphasized by our contact at Horner-Shifrin who argued that a pilot scale operation would not provide adequate information because large boilers function quite differently from a small scale boiler that would be employed in a pilot scale plant.** Thus

* See Appendix C for the scaling of technological uncertainty.

** EPA inquired about the possibility of constructing a pilot scale operation and was convinced by Horner-Shifrin's arguments.
Fig. 1—Flow diagram of processing plant
Fig. 2 — Schematic diagram of Union Electric facilities to receive, store and burn refuse
from the point of view of reducing technological uncertainty, a demonstration project appears to have been the appropriate tool.

The demonstration plant was highly successful in reducing technological uncertainty. It showed that processing involved no serious technological problems and that the performance of solid waste fuel as a heat producer in conjunction with coal was excellent and required no important modifications of the boiler.*

**COST UNCERTAINTY**

At the inception of the demonstration, the uncertainties surrounding the cost of the solid waste fuel alternative were great. The most important aspect of this uncertainty stemmed directly from uncertainty about the technology. Until it was clear that it could be done, and how it could be done, the costs of doing it would remain highly uncertain. The RFD was not planned to allow optimal reduction of cost uncertainty.** (1) Its size (650 tons per day) does not make use of all the economies of scale. (2) Both the processing facility and the firing facilities were constructed with no redundancy. This meant that every time a breakdown occurred in any part of either facility, the entire operation stopped. Thus, continuous operating data were not able to be gathered. As it turned out, however, the resulting loss of information was small. Because of the simplicity of the technology, reasonable cost extrapolations could be made with fragmentary data. In any case, given the sensitivity of costs to local conditions, extensive paper studies of cost would have been necessary even if the system had been designed to maximize the reduction of cost uncertainty in the St. Louis case.

* This applies only to tangentially fired coal burning boilers. A discussion of the applicability of solid waste fuel to other kinds of boilers and in conjunction with other types of fuels will be discussed below under demand uncertainty.

** This was not a case of oversight or improper planning. The decisions about the scale of the plant were made to minimize risk under circumstances involving technological uncertainty. Our contact at Horner-Shifrin said that, in retrospect, they should perhaps have requested more money so that a larger plant with some redundancy could have been built. It is not clear, however, that Union Electric would have been willing to go along with a larger investment until the technology was proved. Union Electric was bearing all of the risk for its investment, while the City and Horner-Shifrin were sharing the risk with the federal government.
Virtually all of the costs associated with a solid waste fuel system are variable depending on local conditions. The capital and operating costs can be divided into three main categories: processing, transportation, and firing.* (See Table 1.) The capital costs of the processing facilities are least variable from site to site, being sensitive only to economies of scale. The upper limit on economies of scale is about 1,500 to 2,000 tons per day, after which diseconomies set in. The slope of cost functions is quite gradual for both economies and diseconomies. This is quite significant because it means that if other conditions are favorable, a solid waste fuel system is an economic alternative for a wide range of city sizes. The range of sizes of plants now under construction is from a 200-ton-per-day plant in Ames, Iowa, involving a capital investment of only three million dollars to an 8,000 ton-per-day plant being constructed by the Union Electric Power Company in St. Louis, involving a capital investment of over 70 million dollars. Transportation costs of moving the fuel from the processing plant to the utility are obviously a function of the location of the processing plant vis-à-vis the utility, the modes of transportation available and their cost. In some cases it will be possible to locate the processing facility adjacent to the utility and transport the fuel via pneumatic pipeline. In other cases, barge, rail, or truck transport are necessary. The capital costs of the firing facilities depends upon the type of boiler in which the fuel will be used. The RFD employed the most convenient boiler to modify for solid waste fuel—a tangentially fired, coal burner. The only modification necessary was the simple addition of solid waste firing ports. Other firing configurations will require more extensive modification and, therefore, greater costs. In oil or gas burning boilers, the costs of ash handling would have to be added.**

The RFD reduced cost uncertainty enough so that relatively straightforward extrapolations can be made to local conditions where the boiler is a tangentially fired coal burner. EPA weighed the possibility of another

---


** Solid waste fuel would not be economic in cases in which the boilers did not already have ash handling capability. Many oil and gas burning boilers, however, are modified coal burners and therefore have ash handling capability. One result of the increases in gas and oil prices has been to increase the attractiveness of coal as a fuel for utilities. This will have a favorable impact on the economics of solid waste fuel use.
Table 1: EPA PROJECTED COSTS FOR A SOLID WASTE FUEL SYSTEM

<table>
<thead>
<tr>
<th>Processing facilities**</th>
<th>Smaller systems (30 tons per hr.)</th>
<th>Larger systems (125 tons per hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost, per ton of daily capacity</td>
<td>$3,500 to $4,500</td>
<td>$2,000 to $3,000</td>
</tr>
<tr>
<td>Capital cost per ton ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical public financing</td>
<td>$1.40 to $1.80</td>
<td>$.80 to $1.20</td>
</tr>
<tr>
<td>Typical private financing</td>
<td>$2.20 to $2.90</td>
<td>$1.30 to $1.90</td>
</tr>
<tr>
<td>Operating costs per ton</td>
<td>$4 to $6</td>
<td>$3.50 to $5.50</td>
</tr>
</tbody>
</table>

Transportation facilities, including amortization

| Simpler cases | $.50 to $1 per ton |
| Complex cases | $5 to $6 per ton |

Firing facilities

| Capital cost, per ton of daily capacity | $3,000 to $3,500 | $2,000 to $2,500 |
| Operating costs, including amortization |

| Favorable circumstances | $.50 to $1 per ton |
| Less favorable circumstances | $2.50 to $5 per ton |

*Our contacts at both Horner-Shifrin and the City of St. Louis thought that these EPA cost figures were slightly on the low side. Neither disputed the way in which the cost figures were obtained, but suggested that EPA had taken the more optimistic calculations. Lowe, op cit., p. 18.

**Basic parameters of the processing facilities: two-stage milling, with air classification after the first hammermill; two eight-hour shifts per day, 250 operating days per year; land costs are not included; residue disposal cost is not included.

***Typical public financing reflects a six percent cost of capital over a 15-year life. Typical private financing reflects a ten percent cost of capital over a ten year life.
demonstration using a gas or oil fired boiler and decided against it, believing that the St. Louis demonstration would provide enough data that a gas or oil system would be attempted without federal assistance. The correctness of that decision is being borne out.* 

As a resource recovery technology, there is another set of calculations which have to be taken into account by a potential adopter—the value of the recovered energy and other resources. The RFD recovered ferrous metal in addition to energy and sold it to a nearby steel mill. The technology exists to add components to the St. Louis system to recover aluminum and other materials which may bring a high price. Local markets are crucial, however. As with the solid waste fuel, the value of other recovered materials declines rapidly with distance from a purchaser. In addition, the components of municipal refuse vary by locality. In St. Louis, for example, there are no aluminum cans which provide the main source of recovered aluminum. (This brings up another aspect in which the technology is flexible in its implementation. Components can be added to fit local conditions. Our conclusion that this will greatly aid in the diffusion of the technology will be discussed below.) The revenue derivable from the recovered resources makes the solid waste fuel system more attractive to potential adopters, but raises a number of questions about demand and institutional changes which will be discussed directly.

DEMAND UNCERTAINTY

To address the issue of demand uncertainty, we first have to ask what the demonstrated technology produces. In order of importance, the RFD produced:

- a means to dispose of municipal refuse
- a fuel
- ferrous scrap

For all three of these products there are well-established markets. The need for a means to dispose of refuse is, of course, universal. In addition, the

* One of the nation's largest utilities, Consolidated Edison of New York, is now working on the design problems of using solid waste fuel in conjunction with fuel oil. With the basic idea of using solid waste as a fuel proved by
traditional means of disposal, land-fill and incineration, are becoming progressively less attractive alternatives to a resource recovery operation for several reasons. Closeby landfills are being depleted in many areas, necessitating increasingly expensive transport. Landfills are also becoming more expensive as environmental laws and regulations applying to them are being enforced. The EPA has proceeded slowly with the enforcement of landfill regulations until recently because of the lack of available alternatives that would not also pose environmental problems. Refractory-lined incinerators, which had been the standard technology where landfill was unavailable, are generally finding it impossible to meet federal standards for air quality, and are therefore being phased out as their capital lives end. In addition traditional incinerators waste their only useful output—heat.

Solid waste fuel systems compete with a number of alternative technologies in the disposal market. (See Table 2.) The decision to adopt a system of the type demonstrated in St. Louis is in substantial part a function of the demand for the other major output—dry solid waste fuel. Unless a stable long term demand for the fuel is available, the capital investment in such a system is unwarranted. Horner-Shifrin, which has been conducting a number of feasibility studies for local communities and utilities, has insisted that its potential customer gain the cooperation of the other major participant before the study is conducted. Only in this way can a stable supply and demand of the fuel be assured, no matter what institutional arrangement is finally worked out for the ownership and operation of the processing facilities. *

As has already been explained above, solid waste fuel is a near perfect substitute for coal in some large boilers. Along one quality dimension it is even superior to coal; sulphur content is very low. Nonetheless, the market for solid waste can never approach the diversity of consumption ("thickness")

the RFD and the price of oil increasing rapidly, it is reasonable to expect that the private sector will be willing to do some investing in research and development.

* Utilities are the major demander of solid waste fuel, but not necessarily the only one. Many large industrial firms maintain their own boilers, and in some cases could become users of solid waste fuel. Even with several buyers of solid waste fuel, the market for the product would remain thin.
Table 7
ECONOMIC AND ENVIRONMENTAL CHARACTERISTICS AND STATUS OF THERMAL REDUCTION AND ENERGY RECOVERY SYSTEMS

<table>
<thead>
<tr>
<th>System</th>
<th>Companies Involved</th>
<th>Capital Costs per Ton of Daily Capacity</th>
<th>Status</th>
<th>Air Pollution Potential</th>
<th>Major Product Output</th>
<th>Marketing Problems</th>
<th>Total Operating Costs per Ton</th>
<th>Revenues Per Ton</th>
<th>Net Costs Per Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incineration: Refractory-</td>
<td>***</td>
<td>15,000-20,000 units</td>
<td>Obsolete; 300 units in use</td>
<td>Cannot economically meet Federal standards</td>
<td>None</td>
<td>--</td>
<td>$8.00-13.00</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>lined units</td>
<td>Nashville Thermal Transfer</td>
<td>12,000-15,000 units</td>
<td>Several units operational, 240 to 1,500 tons per day</td>
<td>Can meet Federal standards</td>
<td>Steam</td>
<td>Must satisfy specific needs of customer</td>
<td>9.00-15.00</td>
<td>$6.00</td>
<td>3.00-15.00</td>
</tr>
<tr>
<td>synthesis:</td>
<td>Garrett Research &amp; Dev.</td>
<td>10,000-18,000 units</td>
<td>200 ton/day pilot plant under construction</td>
<td>Emissions readily controlled</td>
<td>Oil, gas</td>
<td>Oil needs to be tested. Value of gas needs to be increased to extend marketability</td>
<td>10.00-13.50</td>
<td>5.00</td>
<td>5.00-8.50</td>
</tr>
<tr>
<td>Conversion to gas or oil</td>
<td>Co., Union Carbide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat recovery</td>
<td>Monsanto, Tullar, Davco</td>
<td>14,000-18,000 units</td>
<td>1,000 ton/day plant under construction</td>
<td>Emissions readily controlled</td>
<td>Steam</td>
<td>Most satisfy specific needs of customer</td>
<td>9.50-12.50</td>
<td>4.00-5.00</td>
<td>4.50-8.50</td>
</tr>
<tr>
<td>Refuse as fuel: Dry-shredded</td>
<td>Korner &amp; Shifrin, Browning</td>
<td>7,000-13,000 units</td>
<td>650 ton/day system in operation</td>
<td>Air pollution tests currently underway at power plant. Combining two sources into one is an advantage.</td>
<td>Fuel</td>
<td>Major market in coal-fired utility boilers. No major problems expected.</td>
<td>10.00-14.00</td>
<td>5.00</td>
<td>5.00-9.00</td>
</tr>
<tr>
<td>ST. LOUIS RPD</td>
<td>Ferrie, Inc., Waste Man-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>agement, Inc., Combustion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineers, Combustion Equip.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assoc., Americology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet-pulped</td>
<td>Black, Clemson</td>
<td>10,000-14,000 units</td>
<td>Hardware in use; 150 ton/day pilot plant</td>
<td>Fuel Use of pulp as fuel still needs to be tested</td>
<td>31.00-14.00</td>
<td>7.00</td>
<td>4.00-9.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td>Combustion</td>
<td>Research--pilot plant</td>
<td>Emissions should be well below new standards</td>
<td>Electricity Implications of selling electricity are unknown</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>generation</td>
<td>Power Co.</td>
<td>Research--lab scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td>Research--lab scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


** Includes amortization. The range in costs reflects differences in size and dates of original data.

*** Many different companies have constructed this type of system.
of the market for coal, oil, or gas. It cannot be burned economically in small boilers; it must always be burned in conjunction with some other fuel; and because of its bulk, its transportation costs are high per BTU. In any given local area, the market for ferrous metals, either fordetinning or as iron scrap, may also be thin. This again raises the question of how to insure stable markets.

Because the markets for the recovered resources are generally thin, the institutional arrangements to govern the production and use of the outputs become crucial to the decision to adopt. These considerations are included in our conceptual framework under the rubric of institutional uncertainty below.

The demand for solid waste fuel can be expected to strengthen in the coming years because of dramatic increases in the prices of fossil fuels. The long run (i.e., past 20 to 30 years) demand is a good deal less certain according to EPA officials. Only if fossil fuels (and coal in particular) remain very important in the production of electricity will the demand for solid waste fuel such as that produced by the RFD remain strong. Our EPA contacts believe that over the long run, other technologies (e.g., production of gas or oil, or direct production of electricity or steam) may have better futures. For the next 25 to 30 years, however, the demand for solid waste fuel appears to be strong enough to justify large current capital investment.

Because all of the components of the technology for the RFD are off-the-shelf items, uncertainty for manufacturers of the hardware was never an issue for this demonstration. There is little reason to believe that it would become so as the technology diffuses, because the solid waste fuel system market is unlikely to become a large fraction of the sales of any industry producing the components of the systems.

INSTITUTIONAL UNCERTAINTY

The introduction of a new technology is rarely organizationally neutral; it will usually have some impact on the internal operations of an organization, and frequently upon an organization's relationship with other organizations.*

*To be conceptually correct, the impact is on individuals, not "organizations." It is to individuals that the costs and benefits of an innovation accrue, and it is, of course, individuals, not organizations that make the decisions to adopt or reject a technological innovation. We speak in terms of an "organization" for convenience, recognizing the logical fallacy involved.
In our conceptual framework, we assume that uncertainty about the internal and external organizational impact of adopting a technological innovation affects the potential adopter's decision. A demonstration project rarely resolves institutional uncertainties in the manner in which it might resolve uncertainties about the technology. Rather, a demonstration project will be successful in reducing institutional uncertainties if it is able to identify the probable changes in organizational patterns that would result from the adoption of an innovation, and suggest the alternative feasible institutional arrangements in which the innovation might be adopted and put to use. Only in identifying changes from existing patterns and suggesting the alternatives can a demonstration which is specific to a site and set of organizations be generalized by a potential adopter to his own circumstances.

The RFD succeeded in identifying a substantial amount of institutional uncertainty, especially external institutional uncertainty. The introduction of solid waste fuel technology may in some cases involve the fashioning of entirely new institutions; may cause substantial disruption (or even elimination) of some organizations both public and private, and at the very least requires the formation of links between organizations which previously had little contact.

There are three major steps involved in using solid waste as a fuel which are sufficiently distinct that they might easily be performed by different organizations:

- collection of the refuse (extracting the raw material)
- processing of the fuel (production)
- firing (consumption)

In any given area, collection may be handled by a public monopoly, by a private hauling industry, or some combination of the two. Disposal (either incineration or landfill) likewise may be publicly or privately owned. The introduction of a solid waste fuel system may have only slight immediate impact on the collection process, but will likely render the existing refuse disposal operations obsolete. There are four possible organizational arrangements for a solid waste fuel system which vary in the amount and type of vertical integration.
Figure 3
POSSIBLE ORGANIZATIONAL ARRANGEMENTS FOR A SOLID WASTE FUEL SYSTEM

In the type I, all three functions are conducted by a single organization. This type of arrangement will probably occur only where a local government owns the utility or other boiler in which the fuel can be used. This type of arrangement will exist with the Ames, Iowa plant which is under construction. Type I has the advantage of eliminating most external institutional uncertainty. It can be expected to suffer the normal disadvantages of government ownership by eliminating most of the market cues for efficient allocation.

The second type of arrangement, in which the fuel-using organization obtains refuse from municipal or private collectors and processes it, will probably become the most common. The reason that we expect it to be the usual arrangement is that the major users of solid waste fuel, utilities, are typically not owned by the municipalities collecting garbage. A collection system will in every case already be in place. If the utility owns the processing facilities, it gains control over the characteristics of the fuel it is burning. (Our contact at Union Electric stressed the importance of this factor for Union Electric's future plans.) In addition, in at least some cases, there may be a substantial profit incentive for utilities.

Union Electric is making a 70 million dollar investment in solid waste fuel system now, in which Union Electric will own and operate the processing facility through a wholly owned subsidiary, Union Colliery Company. Union Electric is establishing five collection stations in the greater St. Louis area at which dumping fees at or below competitive fees at landfills will
be charged. Union Electric plans to process essentially all of the refuse produced in the metropolitan area.*

From the point of view of the municipalities making use of the system, the type of arrangement planned for St. Louis has a number of distinct advantages. If the municipality now incinerates its refuse, these facilities can be closed. This eliminates a source of air pollution as well as the capital and labor costs associated with the operation of the facilities. A type II arrangement also holds the promise of reduced dumping fees if the municipality now uses private landfills. A possible disadvantage of the type II arrangement is that there will be a strong tendency for the utility processing refuse to become the only disposal source for refuse in an entire region: i.e., a refuse monopsonist. Most landfill operations would be driven out of business, and the lead time for construction of a new incineration facility is long. The re-entry of landfill operations after several years out of the disposal business is quite problematic given that land use patterns could be expected to change. The possible scenario then calls for the utility, having driven competitors out with low dumping fees, to subsequently increase its fees. Several of our contacts in St. Louis voiced this as a fear, particularly in light of Union Electric's decision to make use of Union Colliery which is outside the purview of the Missouri regulatory commissions.** Whether or not these fears are borne out, of course, remains to be seen. One of our contacts


** Union Colliery has been a legally established corporation for many years, but had existed only on paper for the last 30 years or so. Union Electric argues that the use of Union Colliery to receive, process, and then sell the fuel to the parent company was done to prevent the customers of Union Electric from bearing any of the risk involved in the solid waste system.
expressed the opinion that a "healthy" profit by Union Colliery would be advantageous from the viewpoint of speeding the technology's diffusion. In addition, any utility attempting to gain a monopsonist's profit would have to reckon with the possibility of the higher fees resulting in state regulation.

The Type III case would probably involve a municipality collecting the refuse and processing it into fuel, which it would then sell along with any other recovered materials in the existing markets. This type of arrangement is envisioned by the EPA and is already planned for a pyrolysis steam producing plant in Baltimore, Maryland. This arrangement adds a new, and perhaps difficult function to local government—marketing. Finding stable long term markets for the fuel is an obvious prerequisite to the economic success of a solid waste fuel system. This could, perhaps, be accomplished by means of long term contracts with fuel users. The advantage of this arrangement to a municipality is that it would allow the local government to maintain control over its solid waste system and capture all the economic benefits. The RFD formally fit into Type III. St. Louis collected and processed the refuse which was then turned over to Union Electric for actual use.

The Type IV case, in which the collection, processing, and firing are all separated would probably involve a private firm doing the processing and then selling in existing markets. The Type IV case in which there is no vertical integration at all appears unlikely except perhaps in cases where the local government provides disposal facilities, but not collection and there is no potential fuel user that is willing to put up the necessary capital. Despite the fact that a number of institutional arrangements are possible and the RFD demonstrated only one of them, the project did manage to identify most of the problems involved in changing institutional arrangements to accept the innovation and to suggest a number of alternatives that might be worked out to fit local circumstances. (Once again in this dimension as well as others, we note the unusual degree of flexibility in this technological innovation.)

The RFD helped show that in some cases, difficulties with labor unions may arise from the adoption of the solid waste fuel system. In cases in which a municipality maintains substantial disposal facilities, a number of jobs might be lost by the adoption of the technology. Our contacts in St.
Louis were hesitant to discuss the union implications of Union Electric's plan which will render a number of union jobs obsolete. The number of jobs involved in St. Louis is relatively small, and the workers can probably be absorbed into other parts of the Refuse Department. One contact noted a case in which Horner-Shifrin is performing a feasibility study in which the unions pose a potential major barrier to the adoption of the technology. Of course, if a municipality decides to do the processing itself, the job loss could be minimized and even eliminated. The RFD processing facilities did not require the hiring of new personnel. The technology was sufficiently straightforward that the City's engineers had the requisite background. This will likely not prove to be the case with alternative technologies such as gasification and liquefaction of refuse.

UNCERTAINTY ABOUT EXTERNALITIES

In our conceptual framework for the Analysis of Federal Demonstration Projects study, we included questions relating to externalities and their regulation in a separate category of uncertainty that might be fruitfully addressed by a demonstration. In the case of the Refuse Firing Demonstration, externalities and their regulation were explicit reasons for federal participation in the project.

Solid waste is a large and growing problem in the United States. Landfills, even where they are environmentally sound, are often being depleted. Incineration has traditionally been an important source of air pollution. Although current incineration technology can meet pollution standards, these technologies are quite expensive, which places a considerable burden on already pressed local finances. Finally, starting in the 1960's was an awareness that natural resources were not only finite, but that we as a nation were using them up at a rapid rate. In response to this awareness, numerous recycling centers were created often by concerned private groups; sometimes with the aid of local governments. Recycling centers, largely because they are uneconomic and require considerable voluntary participation, are unlikely to prove a long term solution to the problem of lost resources. * A solid

*An additional advantage is that this technology saves on fossil fuels. The importance of the fuel savings can easily be exaggerated, however. In terms of saving scarce fuels, the application of the RFD technology to oil
waste fuel system, be it of the St. Louis type or one of the alternatives, simultaneously meets all of the problems of solid waste disposal. It obviates the need for most landfill; substantially reduces air pollution; promises to be economical; and recovers, in one form or another, a large portion of the resources currently being lost in solid waste. Given the substantial social benefits expected to accrue from the technology, there is a presumption that the private sector would underinvest in the development and demonstration of the technology. The rationale for federal intervention to promote the technology, therefore, was especially strong in this case.

The primary uncertainty in the externality dimension was what the burning of solid waste would do to the emission of pollutants by boilers, and how refuse firing boilers would be regulated. There was never much doubt that if the technology worked it would produce less net air pollution than incineration, simply because two sources of pollution were now being reduced to one. In addition, it was expected that sulphur pollution would decline because refuse contains less sulphur than low sulphur coal. It was also suspected that lower nitrogen oxide emissions would result. The principal unknowns were 1) what effect if any would solid waste fuel have on air pollution control equipment, and 2) what would the level of particulate emissions be. Results thus far indicate that particulate emissions will be higher with solid waste fuel than with coal alone, but not uncontrollably high.\(^\text{a}\) The pollution control equipment appears to perform without difficulty. (Electrostatic precipitators are used at Union Electric.) The fact that emissions will prove slightly higher raises the problem of how utilities burning solid waste fuel are to be regulated.

Federal (and generally state) regulations of air pollution for utilities are much more stringent than for incinerators. These regulations are largely a reflection of what had been technically possible. EPA is presently faced with several alternatives for regulation. It could regulate solid waste

\(^{\text{a}}\)As of this writing a final round of emission tests has just been completed. Final results are not yet available.
burning boilers as it does utilities. The result of this course (which no one we contacted expects) would be to slow the implementation of the technology until emission control technology could cope with the problem. The second alternative would be to regulate the boilers as incinerators, which would generally leave them regulated by local and state standards. The result of this would be to greatly increase the incentive of some utilities to adopt solid waste fuel, but only at the cost of increased pollution. The third and probable course is the setting of emission standards which are attainable using modern pollution control equipment (such as that at Union Electric). This would not pose disincentives to adoption because utilities are being forced to install such equipment anyway, and might even make the meeting of pollution standards slightly easier than it would otherwise be.

It is safe to state that by the conclusion of the demonstration in June, 1975, uncertainty in the externalities dimension will have been nearly eliminated. Not surprisingly, the federal role in the RFD was greatest in this area. Indeed, with respect to externalities the funding agency was the principal target audience.
III. DISSEMINATION AND DIFFUSION

There have been two complementary lines of dissemination of the results of the RFD. EPA has carried on a substantial program of dissemination aimed at specified target audiences. Engineering design firms hoping to design systems similar to the RFD have also been active in spreading the word.

EPA ACTIVITIES

In its few years of existence, the Office of Solid Waste Management Programs has developed an extensive information network which links the primary users of solid waste systems, viz., local governments, with system designers and builders. OSWMP has established itself as the information vortex for solid waste systems. It receives requests for information from local governments, then offers a number of alternative technologies and firms to contact. Private firms developing solid waste systems are eager to get a good evaluation of their system from EPA in order to enter the information network.

Note that Table 2 (page J-18) lists not only alternative technologies, but the major companies involved in designing such systems. The development of an information net by OSWMP has surely been eased by the fact that it has been EPA itself which has rendered a great many of the nation's solid waste disposal techniques suddenly obsolete.

By establishing itself as an information vortex, OSWMP was in a position to act as a market intermediary in the solid waste field. The importance of there being such a link between users (local governments and utilities) and system designers may be particularly important in a situation like the RFD for several reasons. The market for the RFD's technology was only a subset of the whole market for solid waste systems, a subset of the market which had not previously been aggregated. Furthermore, the market for the technology is geographically dispersed; and while significant in the aggregate, it could be characterized as rather thin for any particular firm designing the systems. By acting as an intermediary, OSWMP could lower the information costs to both users and suppliers of the system.

*This is really part of a "market imperfection" argument for government intervention. This argument must be used with some caution, however. The
For the past three years or so, OSWMP has conducted a series of locally based conferences under the sponsorship of such groups as the National League of Cities, the National Conference of Mayors, the International City Manager's Association, and the League of Women Voters. At these local gatherings, presentations were made by the staff and publications on energy and resource recovery systems made available. An important aspect of the OSWMP dissemination efforts is that they are directed at local decision-makers, not at local technical staff. This reflects the make-up of the staff in OSWMP and the Energy Recovery Division in particular. The staff is heavily weighted toward those with business administration degrees, not backgrounds in engineering. As one member of the staff told us, "We see ourselves as salesmen. We try to relate the new systems to the people who have to make the decisions. We talk and write in a language which is understood by them." A review of OSWMP publications on energy and resource recovery systems confirms this point; they are written in nontechnical style and address questions that are most likely to be asked by mayors and councilmen, not engineers.*

No accurate records of visits to the RFD were kept, but one of our contacts in St. Louis said that the number of representatives (for the most part engineers) from local governments, utilities, engineering firms and foreign countries was well into the hundreds.

Private dissemination has been carried primarily by engineering firms hoping to design and/or construct a solid waste fuel system. Six major engineering firms are already in the market (see Table 2). Horner-Shifrin alone has conducted more than 75 feasibility studies for local governments and utilities. Horner-Shifrin has benefited directly from the major role it played in the RFD. Private dissemination is aided not only by EPA's clearing-house function, but by the lack of patents on the system and the technical simplicity of the system.

---

private sector can and does provide market intermediaries in many situations. The appropriateness of OSWMP fulfilling this role in the solid waste field can be defended not only in terms of market imperfections but also significant external economies involved in OSWMP taking on this function. Much of the information necessary to act as a market intermediary would be gathered by OSWMP in the course of their activities whether or not they fulfilled this role.

* See Appendix D for an example dealing with the RFD.
The RFD has compiled a record of adoption which makes it almost unique among the demonstration projects we have examined thus far. Table 3 shows seven areas which have made firm contractual commitments to the construction of a system patterned on the RFD. This has taken place even before the demonstration has reached its conclusion and before final evaluations have been completed. Many other communities are in the active planning stages, and it is safe to assume that by the end of 1975, Table 3 could be considerably expanded. The fact that diffusion has started even before the completion of the project does not suggest that the technology would have been diffused without government intervention. Rather it is a reflection of the fact that most of the uncertainty reduction took place very early in the project as soon as the basic idea was proven, and the rapidity with which the OSWMP began to disseminate the results. Unlike some of our other cases, the role of federal monies in the development of this technology is especially clear. The RFD was made possible by federal money and it was with the RFD that the idea was originated and developed.

We are convinced that one of the most important reasons for the substantial and growing diffusion of this technology is its flexibility. The technology can be tailored to fit local circumstances in terms of scale, and in terms of the number of resources recovered in addition to fuel. A number of different institutional arrangements can be fashioned to fit local circumstances. This flexibility means that the results of the St. Louis demonstration can in fact be generalized to other settings.

The full potential of the RFD technology is not yet known. Consolidated Edison of New York is now conducting a feasibility study of using solid waste fuel in conjunction with oil which, if successful, will open up a substantial new area of application. Even if burning in conjunction with oil is not feasible, which is not the expectation, the diffusion of this simple technology will be substantial.
Table 3
INVESTMENT RESULTING FROM THE ST. LOUIS DEMONSTRATION*

FEDERAL COST:
$3.6 million **

ADOPTERS:

<table>
<thead>
<tr>
<th>City</th>
<th>Tons Per Day</th>
<th>Capital Cost (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames, Iowa</td>
<td>200</td>
<td>$3</td>
</tr>
<tr>
<td>Bridgeport, Conn.</td>
<td>1,800</td>
<td>29</td>
</tr>
<tr>
<td>Chicago, Illinois</td>
<td>1,000</td>
<td>14</td>
</tr>
<tr>
<td>Milwaukee, Wisconsin</td>
<td>1,000</td>
<td>17</td>
</tr>
<tr>
<td>Monroe County, New York</td>
<td>2,000</td>
<td>25</td>
</tr>
<tr>
<td>New Britain, Conn.</td>
<td>1,800</td>
<td>22</td>
</tr>
<tr>
<td>St. Louis area, Mo.</td>
<td>8,000</td>
<td>70</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>15,800</strong></td>
<td><strong>$180</strong></td>
</tr>
</tbody>
</table>

*Prepared by Robert A. Lowe, EPA

**Includes one million dollars for air pollution testing and processing plant evaluations.
IV. CONCLUSION

Why did the Refuse Firing Demonstration in St. Louis succeed so well where so many other demonstrations have failed? Several things are immediately obvious. The technology was ready to be demonstrated. The simplicity of the technology was such that it could be demonstrated at an operational scale, without proceeding through laboratory and pilot plant phases. This was an almost completely apolitical demonstration project, in the sense that it had low political visibility, there were no pressures to sit the project in anybody's district, there were no pressures to speed up the timetable to accommodate a political schedule. The RFD was unusually well-planned. All of the relevant organizations were heavily involved in the planning process, and the planning process was deliberately geared to searching for potential problems. The use of a feasibility study essentially as a planning vehicle seems to have been highly effective. These are the proximate causes of success; there are some underlying causes which we believe are equally crucial.

The RFD involved four organizations each of which had very strong incentives to see the demonstration project be successful. For Horner-Shifrin, Union Electric, and the City there was the prospect of significant economic benefits. For EPA's Office of Solid Waste Management Programs there was the prospect of a highly successful project that could be pointed to at budget time. In addition, individuals in each of these organizations came to be committed to the success of the project. It is our conjecture that the fact that the idea originated and was developed by the same individuals who later became principals in the RFD greatly aided this process of subsequent individual commitments. It was their idea, and they were in a position, with the aid of the federal government, to see it through.

The federal actors in the RFD concentrated on doing what they could do best—provide money, conduct evaluations, and disseminate the results. They stayed out of the planning and operations process almost completely.

In a number of respects, the RFD resembles another demonstration project included in our case studies, the mechanized refuse collection demonstration in Scottsdale, Arizona (dubbed Godzilla). In both cases, the demonstration was conducted by the same people who developed the original idea; in both
cases, the federal agency (EPA) played a largely passive role; in both cases, the technology was simple; both cases addressed significant cost problems for local government. Godzilla was relatively successful in reducing uncertainties, yet the RFD is diffusing rapidly as a system, while Godzilla's piece-meal diffusion has been painfully slow. The few differences in the two demonstrations are revealing. The RFD through the efforts of Horner-Shifrin and EPA Office of Solid Waste Management Programs was quickly and effectively plugged into an existing market for disposal systems. In the Godzilla demonstration there was no counterpart of Horner-Shifrin, i.e., no organization already in the waste collection hardware market which could advance diffusion of the innovation. (The hardware manufacturers showed little interest in the demonstration project even when they were approached by the demonstration's operators for assistance.) For reasons we were unable to ascertain, EPA apparently lost interest in the Godzilla demonstration, and therefore never made a concerted effort to disseminate the results and promote adoption of the innovation.

POSSIBLE LESSONS FOR FEDERAL POLICY

1. The most obvious lesson is to select demonstration projects where the level of technological uncertainty is relatively low. Having the technology fairly well in hand would appear to be a necessary, but not sufficient, condition for a successful demonstration.

2. The RFD, like the MarAd Shipbuilding Program, and DHEW's Computer EKG, incorporated all of the relevant organizations into the demonstration project, including the consumers of the output of the demonstration. There was no possibility of ending up, as the fish protein concentrate demonstration did, with a product nobody wanted. The lesson for policy is: try to include both production and consumption within the demonstration.

3. When selecting those who will conduct a demonstration, carefully examine the incentives of all involved. In cases where the operators of the demonstration have a strong incentive to see the project successful, federal money is leveraged by their extra effort. In the RFD, Horner-Shifrin invested more than was called for; Union Electric's investment was all voluntary.

4. This case study illustrates the advantages of cost sharing between a federal agency and private industry. The saving of federal money that
may result from cost sharing is perhaps the least important reason for doing it. It is in the selection of projects that cost sharing performs its most valuable function if it is done with care. The simple fact that some private firm is willing to invest by cost sharing does not, in and of itself, assure that the idea has substantial merit. The federal agency must try to ascertain the reasons that the private firm is willing to cost share. Some firms may be willing to assume very risky investments, in which case a willingness to cost share would prove nothing. An examination of the firm's investment practices in the past should find some indication as to whether this is the case. In other cases to a very large firm, cost sharing may amount to a very small investment and may represent little more than an attempt to cooperate with a government agency with which it conducts substantial business. The lesson here is to examine the reasons why any given private firm is willing to cost share. Is it because it believes that the idea has enough merit to warrant investment with the government, or is it for reasons extraneous to the innovation itself? How many firms might be willing to share costs on the project? We would guess that in most cases of cost sharing, the federal agency does not even ask the obvious question of the private firm: why are you willing to invest in this technology; what exactly do you believe is in it for you? In the RFD there would have been good reason to believe that the reason for Union Electric's investment was that it hoped for a profitable return. An examination of UE's past practices would have revealed a company that does not make highly speculative investments, and a company with little desire to get involved with government.

Cost sharing requirements may be an even more effective negative screening device in the selection of demonstration projects. If the federal agency can not get any one to cost share, then either the innovation involves a very strong public goods component (in which case the private sector would never produce the good), or (as is more likely) it is an idea which involves risks too substantial to be ready for demonstration. A good example of this is the fish protein concentrate demonstration in which the government first attempted to interest private firms in cost sharing, but could find no
takers. At that point, the whole project should have been reassessed and dropped pending further advances in research and development.*

5. Given that the ultimate goal of most demonstration projects is the diffusion of the technological innovation, careful attention must be paid to the extent to which the experience of the proposed demonstration will be applicable to other potential adopters. A fundamental question which should be asked by federal funders is: to what extent is a proposed demonstration site specific? One of the great advantages for the diffusion of the RFD technology is its flexibility. It is technologically flexible in that the system can be designed with different kinds of components depending upon the number of resources one wishes to recover. It can be built at large or small scale without great losses in efficiency. It is also "institutionally" flexible in that ownership and operation can be established in a number of different ways. The result is that the RFD technology is not of the "accept it or reject it" variety; it can be modified to fit local circumstances.

6. Stick to basics. The RFD did not attempt to provide the most technically advanced and complete system possible. Rather it proved that the basic concept of burning refuse in conjunction with coal was technically and economically sound. The RFD could have incorporated features to recover other resources; the RFD could have attempted the burning of refuse in boilers requiring substantial modification. The risk of doing so would be to increase the level of technological uncertainty. It may well be that a demonstration project is judged by potential adopters more on the basis of what goes wrong than what goes right. Even if a component of a system is peripheral to the main goals of the demonstration, its failure to operate successfully may poison the diffusion efforts.

7. The federal agency should concentrate its efforts in those areas of uncertainty which are crucial and not fully addressed by the operators. The RFD represented a division of labor in uncertainty reduction; the operators of the agency concentrated on the reduction of technological uncertainty;

*We recognize, of course, that the reason the FPC demonstration was not dropped was because of political pressures on the agency to pursue the program to the demonstration stage. This reinforces what we already know—political pressure directly on the selection of demonstration projects greatly increases the chances of poor results.
EPA concentrated its efforts on the evaluation of externalities and costs which it could do without directly intervening in the operation of the demonstration. Of its 3.6 million dollar investment in the RFD, EPA spent fully one million on evaluation. A heavy investment in evaluation activities makes good sense from the point of view of our framework. If one of the main goals of a demonstration is to produce information, investing in evaluation assures that all of the information produced by the demonstration will, in fact, become available.

8. Careful planning, involving all of the actors in the subsequent demonstration, pays off. Because all relevant organizations were heavily involved in the planning process, all possible problems could be explored before construction of the RFD began.
SOLID WASTE DISPOSAL ACT

[Public Law 89-272—89th Congress, S. 308, Approved October 20, 1965]

AN ACT To authorize a research and development program with respect to solid-waste disposal, and for other purposes.

TITLE II—SOLID WASTE DISPOSAL

SHORT TITLE

Sec. 201. This title (hereinafter referred to as "this Act") may be cited as the "Solid Waste Disposal Act".

FINDINGS AND PURPOSES

Sec. 202. (a) The Congress finds—

1. that the continuing technological progress and improvement in methods of manufacture, packaging, and marketing of consumer products has resulted in an ever-mounting increase, and in a change in the characteristics, of the mass of material discarded by the purchaser of such products;

2. that the economic and population growth of our Nation, and the improvements in the standard of living enjoyed by our population, have required increased industrial production to meet our needs, and have made necessary the demolition of old buildings, the construction of new buildings, and the provision of highways and other avenues of transportation, which, together with related industrial, commercial, and agricultural operations, have resulted in a rising tide of scrap, discarded, and waste materials;

3. that the continuing concentration of our population in expanding metropolitan and other urban areas has presented these communities with serious financial, management, intergovernmental, and technical problems in the disposal of solid wastes resulting from the industrial, commercial, domestic, and other activities carried on in such areas;

4. that inefficient and improper methods of disposal of solid wastes result in scenic blights, create serious hazards to the public health, including pollution of air and water resources, accident hazards, and increase in rodent and insect vectors of disease,

Title I of P.L. 89-272 amended the Clean Air Act (P.L. 83-203).

1
have an adverse effect on land values, create public nuisances, otherwise interfere with community life and development;
(5) that the failure or inability to salvage and reuse such materials economically results in the unnecessary waste and depletion of our natural resources; and
(6) that while the collection and disposal of solid wastes should continue to be primarily the function of State, regional, and local agencies, the problems of waste disposal as set forth above have become a matter national in scope and in concern and necessitate Federal action through financial and technical assistance and leadership in the development, demonstration, and application of new and improved methods and processes to reduce the amount of waste and unsalvageable materials and to provide for proper and economical solid-waste disposal practices.

(b) The purposes of this Act therefore are—
(1) to promote the demonstration, construction, and application of solid waste management and resource recovery systems which preserve and enhance the quality of air, water, and land resources;
(2) to provide technical and financial assistance to States and local governments and interstate agencies in the planning and development of resource recovery and solid waste disposal programs;
(3) to promote a national research and development program for improved management techniques, more effective organizational arrangements, and new and improved methods of collection, separation, recovery, and recycling of solid wastes, and the environmentally safe disposal of nonrecoverable residues;
(4) to provide for the promulgation of guidelines for solid waste collection, transport, separation, recovery, and disposal systems; and
(5) to provide for training grants in occupations involving the design, operation, and maintenance of solid waste disposal systems.

DEFINITIONS

SEC. 203. When used in this Act:
(1) "Secretary" means the Secretary of Health, Education, and Welfare, except that such term

means the Secretary of the Interior with respect to problems of solid waste resulting from the extraction, processing, or utilization of minerals or fossil fuels where the generation, production, or reuse of such waste is or may be controlled within the extraction, processing, or utilization facilities or facilities and where such control is a feature of the technology or economy of the operation of such facility or facilities.

(2) The term "State" means a State, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, and American Samoa.

(3) The term "interstate agency" means an agency of two or more municipalities in different States, or an agency established by two or more States, with authority to provide for the disposal of solid wastes and serving two or more municipalities located in different States.

(4) The term "solid waste" means garbage, refuse, and other discarded solid materials, including solid waste materials resulting from industrial, commercial, and agricultural operations, and from community activities, but does not include solids or dissolved material in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial waste water effluents, dissolved materials in irrigation return flows or other common water pollutants.

(5) The term "solid-waste disposal" means the collection, storage, treatment, utilization, processing, or final disposal of solid waste.

(6) The term "construction," with respect to any project of construction under this Act, means (A) the erection or building of new structures and acquisition of lands or interests therein, or the acquisition, replacement, expansion, remodeling, alteration, modernization, or extension of existing structures, and (B) the acquisition and installation of initial equipment of, or required in connection with, new or newly acquired structures or the expanded, remodeled, altered, modernized or extended part of existing structures (including tracks and other motor vehicles, and tractors, cranes, and other machinery) necessary for the proper utilization and operation of the facility after completion of the project and includes preliminary planning to determine the economic and engineering feasibility and the public health and safety aspects of the project, the engineering, architectural, legal, fiscal, and economic investigations and studies, and any surveys, designs, plans, working drawings, specifications, and other action necessary for the carrying out of the project, and (C) the inspection and supervision of the process of carrying out the project to completion.

(7) the term "municipality" means a city, town, borough, county, parish, district, or other public body created or pursuant to State law with responsibility for
an Indian tribe.

9. The term "intermunicipal agency" means an agency established by two or more municipalities with responsibility for planning or administration of solid waste disposal.

10. The term "recovered resources" means materials or energy recovered from solid wastes.

11. The term "resource recovery system" means a solid waste management system which provides for collection, separation, recycling, and recovery of solid wastes, including disposal of nonrecoverable waste residues.

RESEARCH, DEMONSTRATIONS, TRAINING, AND OTHER ACTIVITIES

(a) The Secretary shall conduct, and encourage, cooperate with, and render financial and other assistance to appropriate public (whether Federal, State, interstate, or local) authorities, agencies, and institutions, private agencies and institutions, and individuals in the conduct of, and promote the coordination of, research, investigations, experiments, training, demonstrations, surveys, and studies relating to—

1. any adverse health and welfare effects of the release into the environment of material present in solid waste, and methods to eliminate such effects;

2. the operation and financing of solid waste disposal programs;

3. the reduction of the amount of such waste and unsalvageable waste materials;

4. the development and application of new and improved methods of collecting and disposing of solid waste and processing and recovering materials and energy from solid wastes; and

5. the identification of solid waste components and potential materials and energy recoverable from such waste components.

(b) In carrying out the provisions of the preceding subsection, the Secretary is authorized to—

1. collect and make available, through publications and other appropriate means, the results of, and other information pertaining to, such research and other activities, including appropriate recommendations in connection therewith;

2. cooperate with public and private agencies, institutions, and organizations, and with any industries involved, in the preparation and the conduct of such research and other activities; and

3. make grants-in-aid to public or private agencies, training projects, surveys, and demonstrations (including construction of facilities), and provide for the conduct of research, training, surveys, and demonstrations by contract with public or private agencies and institutions and with individuals; and such contracts for research or demonstrations or both (including contracts for construction) may be made in accordance with and subject to the limitations provided with respect to research contracts of the military departments in title 10, United States Code, section 2653, except that the determination, approval, and certification required thereby shall be made by the Secretary.

(c) Any grant, agreement, or contract made or entered into under this section shall contain provisions effective to ensure that all information, uses, processes, patents and other developments resulting from any activity undertaken pursuant to such grant, agreement, or contract will be made readily available on fair and equitable terms to industries utilizing methods of solid-waste disposal and industries engaging in furnishing devices, facilities, equipment, and supplies to be used in connection with solid-waste disposal. In carrying out the provisions of this section, the Secretary and each department, agency, and officer of the Federal Government having functions or duties under this Act shall make use of and adhere to the Statement of Government Patent Policy which was promulgated by the President in his memorandum of October 10, 1963. (3 CFR, 1963 Supp., p. 293.)

SPECIAL STUDY AND DEMONSTRATION PROJECTS ON RECOVERY OF USEFUL ENERGY AND MATERIALS

(a) The Secretary shall carry out an investigation and study to determine—

1. means of recovering materials and energy from solid waste, recommended uses of such materials and energy for national or international welfare, including identification of potential markets for such recovered resources, and the impact of distribution of such resources on existing markets;

2. changes in current product characteristics and production and packaging practices which would reduce the amount of solid waste;

3. methods of collection, separation, and containerization which will encourage efficient utilization of facilities and contribute to more effective programs of reduction, reuse, or disposal of wastes; and

4. the use of Federal procurement to develop market demand for recovered resources;

*Sec. 204(a) amended by Sec. 103, P.L. 91-512.

*Sec. 205 added by sec. 104(a) of P.L. 91-512.
(5) recommended incentives (including Federal grants, loans, and other assistance) and disincentives to accelerate the reclamation or recycling of materials from solid wastes, with special emphasis on motor vehicle hulks;

(6) the effect of existing public policies, including subsidies and economic incentives and disincentives, percentage depletion allowances, capital gains treatment and other tax incentives and disincentives, upon the recycling and reuse of materials, and the likely effect of the modification or elimination of such incentives and disincentives upon the reuse, recycling and conservation of such materials; and

(7) the necessity and method of imposing disposal or other charges on packaging, containers, vehicles, and other manufactured goods, which charges would reflect the cost of final disposal, the value of recoverable components of the item, and any social costs associated with nonrecycling or uncontrolled disposal of such items.

The Secretary shall from time to time, but not less frequently than annually, report the results of such investigation and study to the President and the Congress.

(b) The Secretary is also authorized to carry out demonstration projects to test and demonstrate methods and techniques developed pursuant to subsection (a).

(c) Section 204 (b) and (c) shall be applicable to investigations, studies, and projects carried out under this section.

INTERSTATE AND INTERLOCAL COOPERATION

Sec. 206. The Secretary shall encourage cooperative activities by the States and local governments in connection with solid-waste disposal programs; encourage where practicable, interstate, interlocal, and regional planning for, and the conduct of, interstate, interlocal, and regional solid-waste disposal programs; and encourage the enactment of improved and, so far as practicable, uniform State and local laws governing solid-waste disposal.

Sec. 207. (a) The Secretary may from time to time, upon such terms and conditions consistent with this section as he finds appropriate to carry out the purposes of this Act, make grants to State, interstate, municipal, and intermunicipal agencies, and organizations composed of public officials which are eligible for assistance under section 701 (g) of the Housing Act of 1954, of not to exceed 60% per centum of the cost in the case of an application with respect to an area including only one municipality, and not to exceed 75 per centum of the cost in any other case, of—

(1) making surveys of solid waste disposal practices and problems within the jurisdictional areas of such agencies and

(2) developing and revising solid waste disposal plans as part of regional environmental protection systems for such areas, providing for recycling or recovery of materials from wastes whenever possible and including planning for the reuse of solid waste disposal areas and studies of the effect and relationship of solid waste disposal practices on areas adjacent to waste disposal sites,

(3) developing proposals for projects to be carried out pursuant to section 208 of this Act, or

(4) planning programs for the removal and processing of abandoned motor vehicle hulks.

(b) Grants pursuant to this section may be made upon application therefor which—

(1) designates or establishes a single agency (which may be an interdepartmental agency) as the sole agency for carrying out the purposes of this section for the area involved;

(2) indicates the manner in which provision will be made to assure full consideration of all aspects of planning essential to area-wide planning for proper and effective solid waste disposal consistent with the protection of the public health and welfare, including such factors as population growth, urban and metropolitan development, land use planning, water pollution control, air pollution control, and the feasibility of regional disposal and recovery programs;

(3) sets forth plans for expenditure of such grant, which plans provide reasonable assurance of carrying out the purposes of this section;

(4) provides for submission of such reports of the activities of the agency in carrying out the purposes of this section, in such form and containing such information, as the Secretary may from time to time find necessary for carrying out the purposes of this section and for accounting for such records and accounting for funds paid to the agency under this section.
(c) The Secretary shall make a grant under this section only if he finds that there is satisfactory assurance that the planning of solid waste disposal is coordinated, so far as practicable, with and not duplicative of other related State, interstate, regional, and local planning activities, including those financed in part with funds pursuant to section 701 of the Housing Act of 1954.

GRANTS FOR RESOURCE RECOVERY SYSTEMS AND IMPROVED SOLID WASTE DISPOSAL FACILITIES

SEC. 208. (a) The Secretary is authorized to make grants pursuant to this section to any State, municipal, or interstate or intermunicipal agency for the demonstration of resource recovery systems or for the construction of new or improved solid waste disposal facilities.

(b) (1) Any grant under this section for the demonstration of a resource recovery system may be made only if it (A) is consistent with any plans which meet the requirements of section 207(b)(2) of this Act; (B) is consistent with the guidelines recommended pursuant to section 209 of this Act; (C) is designed to provide area-wide resource recovery systems consistent with the purposes of this Act, as determined by the Secretary, pursuant to regulations promulgated under subsection (d) of this section; and (D) provides an equitable system for distributing the costs associated with construction, operation, and maintenance of any resource recovery system among the users of such system.

(2) The Federal share for any project to which paragraph (1) applies shall not be more than 75 percent.

(e) (1) A grant under this section for the construction of a new or improved solid waste disposal facility may be made only if—

(A) a State or interstate plan for solid waste disposal has been adopted which applies to the area involved, and the facility to be constructed (i) is consistent with such plan, (ii) is included in a comprehensive plan for the area involved which is satisfactory to the Secretary for the purposes of this Act, and (iii) is consistent with the guidelines recommended under section 209, and

(B) the project advances the state of the art by applying new and improved techniques in reducing the environmental impact of solid waste disposal, in achieving recovery of energy or resources, or in recycling useful materials.

(2) The Federal share for any project to which paragraph (1) applies shall not be more than 50 percent in

the case of a project serving an area which includes only one municipality, and not more than 75 percent in any other case.

(d) (1) The Secretary, within ninety days after the date of enactment of the Resource Recovery Act of 1970, shall promulgate regulations establishing a procedure for awarding grants under this section which—

(A) provides that projects will be carried out in communities of varying sizes, under such conditions as will assist in solving the community waste problems of urban-industrial centers, metropolitan regions, and rural areas, under representative geographic and environmental conditions; and

(B) provides deadlines for submission of, and action on, grant requests.

(2) In taking action on applications for grants under this section, consideration shall be given by the Secretary (A) to the public benefits to be derived by the construction and the propriety of Federal aid in making such grant; (B) to the extent applicable, to the economic and commercial viability of the project (including contractual arrangements with the private sector to market any resources recovered); (C) to the potential of such project for general application to community solid waste disposal problems; and (D) to the use by the applicant of comprehensive regional or metropolitan area planning.

(e) A grant under this section—

(1) may be made only in the amount of the Federal share of (A) the estimated total design and construction costs, plus (B) in the case of a grant to which subsection (b)(1) applies, the first-year operation and maintenance costs;

(2) may not be provided for land acquisition or (except as otherwise provided in paragraph (1)(B)) for operating or maintenance costs;

(3) may not be made until the applicant has made provision satisfactory to the Secretary for proper and efficient operation and maintenance of the project (subject to paragraph (1)(B)); and

(4) may be made subject to such conditions and requirements, in addition to those provided in this section, as the Secretary may require to properly carry out his functions pursuant to the Act.

For purposes of paragraph (1), the non-Federal share may be in any form, including, but not limited to, lands or interests therein needed for the project or personal property or services, the value of which shall be determined by the Secretary.

(f) (1) Not more than 15 percent of the total of funds authorized to be appropriated under section 216(a)(5) for any fiscal year to carry out this section shall be granted under this section for projects in any one State.

*SEC. 208 added by sec. 104(b), P.L. 91–512.
(2) The Secretary shall prescribe by regulation the manner in which this subsection shall apply to a grant under this section for a project in an area which includes all or part of more than one State.

RECOMMENDED GUIDELINES

SEC. 209. (a) The Secretary shall, in cooperation with appropriate State, Federal, interstate, regional, and local agencies, allowing for public comment by other interested parties, as soon as practicable after the enactment of the Resource Recovery Act of 1970, recommend to appropriate agencies and publish in the Federal Register guidelines for solid waste recovery, collection, separation, and disposal systems (including systems for private use) which shall be consistent with public health and welfare, and air and water quality standards and adaptable to appropriate land-use plans. Such guidelines shall apply to such systems whether on land or water and shall be revised from time to time.

(b) (1) The Secretary shall, as soon as practicable, recommend model codes, ordinances, and statutes which are designed to implement this section and the purposes of this Act.

(2) The Secretary shall issue to appropriate Federal, interstate, regional, and local agencies information on technically feasible solid waste collection, separation, disposal, recycling, and recovery methods, including data on the cost of construction, operation, and maintenance of such methods.

GRANTS OR CONTRACTS FOR TRAINING PROJECTS

SEC. 210. (a) The Secretary is authorized to make grants to, and contracts with, any eligible organization. For purposes of this section the term "eligible organization" means a State or interstate agency, a municipality, educational institution, and any other organization which is capable of effectively carrying out a project which may be funded by grant under subsection (b) of this section.

(b) (1) Subject to the provisions of paragraph (2), grants or contracts may be made to pay all or a part of the costs, as may be determined by the Secretary, of any project operated or to be operated by an eligible organization, which is designed—

(A) to develop, expand, or carry out a program (which may combine training, education, and employment) for training persons for occupations involving the management, supervision, design, operation, or maintenance of solid waste disposal and resources recovery equipment and facilities; or

(B) to train instructors and supervisory personnel to train or supervise persons in occupations involving the design, operation, and maintenance of solid waste disposal and resource recovery equipment and facilities.

(2) A grant or contract authorized by paragraph (1) of this subsection may be made only upon application to the Secretary at such time or times and containing such information as he may prescribe, except that no such application shall be approved unless it provides for the same procedures and reports (and access to such reports and to other records) as is required by section 207 (b) (4) and (5) with respect to applications made under such section.

(c) The Secretary shall make a complete investigation and study to determine—

(1) the need for additional trained State and local personnel to carry out plans assisted under this Act and other solid waste and resource recovery programs;

(2) means of using existing training programs to train such personnel; and

(3) the extent and nature of obstacles to employment and occupational advancement in the solid waste disposal and resource recovery field which may limit either available manpower or the advancement of personnel in such field.

He shall report the results of such investigation and study, including his recommendations to the President and the Congress not later than one year after enactment of this Act.

APPLICABILITY OF SOLID WASTE DISPOSAL GUIDELINES TO EXECUTIVE AGENCIES

SEC. 211. (a) (1) If—

(A) an Executive agency (as defined in section 106 of title 5, United States Code) has jurisdiction over any real property or facility the operation or administration of which involves such agency in solid waste disposal activities, or

(B) such an agency enters into a contract with any person for the operation by such person of any Federal property or facility, and the performance of such contract involves such person in solid waste disposal activities, then such agency shall insure compliance with the guidelines recommended under section 209 and the purposes
of this Act in the operation or administration of such property or facility, or the performance of such contract, as the case may be.

(2) Each Executive agency which conducts any activity—

(A) which generates solid waste, and

(B) which, if conducted by a person other than such agency, would require a permit or license from such agency in order to dispose of such solid waste, shall insure compliance with such guidelines and the purposes of this Act in conducting such activity.

(3) Each Executive agency which permits the use of Federal property for purposes of disposal of solid waste shall insure compliance with such guidelines and the purposes of this Act in the disposal of such waste.

(4) The President shall prescribe regulations to carry out this subsection.

(b) Each Executive agency which issues any license or permit for disposal of solid waste shall, prior to the issuance of such license or permit, consult with the Secretary to assure compliance with guidelines recommended under section 209 and the purposes of this Act.

NATIONAL DISPOSAL SITES STUDY

Sec. 212. The Secretary shall submit to the Congress no later than two years after the date of enactment of the Resource Recovery Act of 1970, a comprehensive report and plan for the creation of a system of national disposal sites for the storage and disposal of hazardous wastes, including radioactive, toxic chemical, biological, and other wastes which may endanger public health or welfare. Such report shall include: (1) a list of materials which should be subject to disposal in any such site; (2) current methods of disposal of such materials; (3) recommended methods of reduction, stabilization, neutralization, recovery, or disposal of such materials; (4) an inventory of possible sites including existing land or water disposal sites operated or licensed by Federal agencies; (5) an estimate of the cost of developing and maintaining sites including consideration of means for distributing the short- and long-term costs of operating such sites among the users thereof; and (6) such other information as may be appropriate.

LABOR STANDARDS

50 U.S.C. 461

Sec. 213. No grant for a project of construction under this Act shall be made unless the Secretary finds that the application contains or is supported by reason-

---

4 Sec. 215 as redesignated by sec. 104(b) of P.L. 91-512. 5 Sec. 216 as redesignated by sec. 104(b) of P.L. 91-512 (a) of P.L. 91-512. 6 Sec. 217 through 216 as redesignated as sec. 213 through 216 by sec. 104(b) of P.L. 91-512.
not to exceed $140,000,000 for the fiscal year ending June 30, 1973, and not to exceed $140,000,000 for the fiscal year ending June 30, 1974.\footnote{17 P.L. 90-14 extended authorization of funding to June 30, 1974.}

(b) There are authorized to be appropriated to the Secretary of the Interior to carry out this Act not to exceed $8,750,000 for the fiscal year ending June 30, 1971, not to exceed $20,000,000 for the fiscal year ending June 30, 1972, not to exceed $22,500,000 for the fiscal year ending June 30, 1973, and not to exceed $22,500,000 for the fiscal year ending June 30, 1974.\footnote{17 Prior to expending any funds authorized to be appropriated by this subsection, the Secretary of the Interior shall consult with the Secretary of Health, Education, and Welfare to assure that the expenditure of such funds will be consistent with the purposes of this Act.} Prior to expending any funds authorized to be appropriated by this subsection, the Secretary of the Interior shall consult with the Secretary of Health, Education, and Welfare to assure that the expenditure of such funds will be consistent with the purposes of this Act.

(c) Such portion as the Secretary may determine, but not more than 1 per centum, of any appropriation for grants, contracts, or other payments under any provision of this Act for any fiscal year beginning after June 30, 1970, shall be available for evaluation (directly, or by grants or contracts) of any program authorized by this Act.

(d) Sums appropriated under this section shall remain available until expended.
Appendix B *

ALTERNATIVE TECHNOLOGIES--OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS

The alternative technologies being demonstrated by the Office of Solid Waste Management Programs are as follows:

(1) Shredded Waste as a Fuel Substitute or Compost, Wilmington, Delaware. Most of the technology for this system is similar to the St. Louis Refuse Firing Demonstration. Part of the shredded waste, however, will be mixed with sludge in aerobic digesters for use either as fuel or compost.

(2) Wet Pulping for Material Recovery, Franklin, Ohio. This system employed a wet grinder which pulps the incoming refuse and allows paper fiber to be recovered in addition to all other reusable materials. This system is operational and may be included as a case study in Phase II of the study.

(3) Pyrolysis to produce fuel oil, San Diego County, California. This energy recovery system uses flash pyrolysis (rapid heating in the absence of oxygen) to produce an oil with 75 percent of the heating value of number six fuel oil by distilling the pyrolysis gases. The major advantage of this process is that it results in a product which is flexible in its use. The major disadvantage is technological uncertainty and uncertain costs.

(4) Pyrolysis for steam generation, Baltimore, Maryland. This system is being designed and constructed by the Monsanto Corporation under a contract with moneyback provisions if specifications are not met. This pyrolysis system employs an after burner boiler to produce 200,000 pounds of steam per hour which will be sold to the Baltimore Gas and Electric Company. Use of this system depends upon a readily available market for steam.

(5) Incinerator Residue Separation, Lowell, Massachusetts. This system will recover materials such as steel, glass and non-ferrous metals using

technology developed by the United States Bureau of Mines for ore benefi-
ciation. This system should result in a net profit of about 40 cents per
ton processed. The incineration costs will not be affected, and air pollu-
tion from incineration will have to be controlled.
Appendix C

SCALING TECHNOLOGICAL UNCERTAINTY

In our conceptual framework we hypothesized that the most crucial uncertainty in a demonstration project would be the extent to which the technology involved was in hand. Indeed the usual distinctions between technological demonstration projects and experiments and development projects on the one hand, and capital grants on the other are usually made on the basis of the extent to which the technology is developed. Without accepting or rejecting such definitions, it is important to note that projects have been labeled demonstrations by the funding agencies where the level of development of the technology ranges from still in the research stage to where the technology is not only fully developed but widely applied.

In order to establish a basis for comparison of demonstration projects, a scale was established to measure at least in an approximate way the amount of technological uncertainty involved in a demonstration project. The scale consists of two dimensions: (1) the number of component technologies involved in the demonstration (such as a major subsystem) and (2) the amount of technological change required in each component technology if the demonstration is to be successfully applied. The importance of the second dimension is obvious: if one of the required components is still in the R&D stage, successful application of the technology is much more difficult than if the component is off-the-shelf. The first dimension gives a measure of the complexity of the system being demonstrated. A new system being demonstrated may consist of only off-the-shelf components, but because the number of components is large the integration of these components may prove very difficult.
In Table 4, the Refuse Firing Demonstration is scaled. As has already been explained above, this demonstration involved low levels of technological uncertainty, even though the system was entirely new. The hammermill, the air classifier, and the firing technology had all been used on the same scale. They only required new integration for use in the RFD.
<table>
<thead>
<tr>
<th>Firing Process</th>
<th>Air Classifier (separation process)</th>
<th>Hammermill (grinding process)</th>
<th>Technology of Demonstration as a Whole</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Component Technologies

Amount of Technological Change Required

- Red not yet completed
- Technology scale-up from prototype
- No new knowledge, but requires new integration
- No new knowledge, but requires new integration
- No new knowledge, but requires new integration
- Red not yet completed

Fundamentally new problems, with R&D either not started or substantially modified. Small scale use or requires scale up from pilot or other scale. No new knowledge, but requires new integration. None of these technologies has been used successfully. No technological change required.
This is the final section to EPA's basic pamphlet to local governments on the St. Louis RDF, *Energy From Solid Waste*. It is significant to note the nontechnical style in which the section is written and the basic types of questions which it addresses. These issues of results, applicability, and financing are the ones most likely to be of interest to those charged with making actual decisions about what kind of waste disposal system will be chosen for their communities. Technical information, which would be as likely to confuse as enlighten most decision-makers is left to other publications and to engineering design firms who are marketing the system.

SOME ALTERNATIVES TO THINK ABOUT

Q *If I want to consider this system for my community, what issue should I look at first?*
A Markets for fuel. Markets for recovered products are critical to the success of any resource recovery system.

Q *Where are the markets for solid waste fuel?*
A Both utilities and private industrial plants are potential customers for solid waste fuel. The most important prerequisites are that their boilers have ash-handling capabilities and that they be located within an economical transport distance.

Q *Are any communities looking at implementing a solid-waste-as-a-fuel system?*
A Yes. At least five cities and utilities are publicly committed to fuel recovery from solid waste. The Connecticut State Solid Waste Management Plan has identified energy recovery as its principal component. At least 25 other utilities and seven private industries have expressed an interest in using solid waste as a fuel.

Q *How much of the fuel is replaced by solid waste?*
A Although the system in St. Louis was originally designed to replace 10 percent of the coal with solid waste fuel on the basis of heating value, the system operated well at a 15 percent replacement rate. Utility personnel say that 20 percent is realistic. Further testing is planned to determine the maximum percentage of the fuel that can be replaced by solid waste.

Q *Union Electric Company has been burning solid waste fuel as a supplement to coal in tangentially suspension-fired boilers. Are there any other possibilities?*
A It appears that solid waste can be used economically as a fuel in any boiler that has bottom ash-handling and particulate emission control facilities. This includes front-fired, opposed-fired, cyclone-fired, and stoker-fired boilers. It also includes boilers currently burning gas or oil.
Q This system is applicable only to large cities. True?
A Not necessarily. Depending on local conditions, energy recovery may be the best alternative in smaller communities as well as large. The critical conditions are alternative disposal costs, the availability of a boiler, alternative fuel costs, and public opinion about resource recovery.

Q What about bulky wastes?
A The capability of a fuel-processing plant to accept bulky wastes is simply a function of design. Shredders and conveyors must be sized to handle larger materials. Any noncombustible or oversized material will be separated from the waste fuel by the air classification process. In general, bulky wastes add little to the heating value of the fuel.

The luxury of disposing of both bulky wastes and municipal wastes at the same facility must be weighed against the added cost to the shredded fuel system.

Q Why should I process solid waste into fuel if sanitary landfilling is less expensive?
A If sanitary landfilling is less expensive, then you probably should continue to landfill. However, some communities have indicated that noneconomic factors are important, too, even at a premium in cost. This is not so surprising as it first appears. For example, if the additional disposal cost per ton is $3, the average person would have to pay only $3 more per year. The environmental benefits may be worth the small extra cost. Moreover, the recovery of energy at a time of energy shortage is sure to provide a real community benefit.

Q How much energy can be recovered from solid waste?
A The potential energy available from solid waste is significant. If energy recovery were practiced in all urbanized areas in the United States, an estimated 800 trillion Btu's could be utilized annually by 1975. Solid waste is a growing energy source: by 1990, an estimated 1.2 quadrillion Btu's will be available from residential and commercial solid waste in urbanized areas.

In comparison, the potential energy in urbanized areas in the solid waste generated in 1970 in urbanized areas could have supplied two-thirds of the Nation's residential and commercial lighting needs, or about one percent of the Nation's total energy consumption.

Financing Alternatives

Q Like any capital-intensive high-technology project, an investment in solid waste processing facilities involves some risk. How can this risk be defined?
A There are three forms of risk exposure.
1. Risk that the town and its economy will not generate the predicted waste stream.
2. Risk that a future technological breakthrough will render the present system obsolete.
3. Risk that the proposed plan incorporating technology, financing, and operating structure cannot meet its predicted performance.

Q How does one deal with the waste generation risk?
A There is essentially no waste generation risk if the system provides a disposal alternative at a competitive dump fee. If a close-in sanitary landfill site is not available, and if open dumps are prohibited, then there will be no cost-competitive alternative for disposal other than the resource recovery system.

Q How does one deal with the risk of obsolescence?
A Milling of solid waste is applicable in many resource recovery technologies. The risk therefore is limited to the end use of the organic fraction. This kind of risk is inherent in any long-term venture.

Q How can the risk of performance, the ultimate financial risk, be assigned?
A The financial risk can be assigned in a variety of ways, depending upon the financing arrangement. There are basically six alternatives:

1. Town bears complete risk. Here the town raises funds through general obligation bonds and directly or indirectly operates the facility.

2. Town indirectly bears complete risk. Here the town would raise funds through revenue bonds with debt service guaranteed by the town. Some “Authority” would be the financing vehicle and a public or private concern would be contracted for operation over a long term.

3. Contractor/operator bears complete risk. Contractor/operator finances by his own means the construction and operation of the system on the basis of a long-term contract with the town.

4. Contractor/operator and revenue bondholders bear complete risk. Here the town would raise special revenue bonds secured solely by revenues from the operations or first lien on the financed facility, or both operations and first lien. Revenue bondholders would have indirect control over operation.

5. Revenue bondholders bear complete risk. As in alternative 4, the town would raise special revenue bonds secured solely by revenues from operations or first lien on the financed facility or both. Revenue bondholders through an agent would have control over the operation.

6. Bondholders and equity investors and contractor/operator bear complete risk. This would be essentially the same as alternative 5, except that bondholders may want equity investors seeking tax advantages to bear some of the risk. The return to equity investors would, for the most part, result from the investment tax credit and accelerated depreciation provisions of the tax law.

The cost to the community varies with each financing alternative. Each community must assess its own opportunities. It bears repeating that the effect of the financing alternative on the cost to the community is so significant that the financing mechanism must be designed as early in the project’s planning stages as possible.
BIBLIOGRAPHY


