Chapter 9

Community Energy Generation

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Introduction

Water power has been a major domestic energy source since the colonial era and was first used to generate electricity commercially in Appleton, Wis., in 1882. Today, hydropower is the most widely used renewable source of energy to generate electricity in the United States, with a total generating capacity of about 64,000 megawatts (MW), or between 13 and 15 percent of the Nation's total supply of electrical energy.[1] Hydropower is also a cheap source of electricity: existing hydropower facilities produce electricity for as little as 3.5 mills (0.35 cents) per kilowatt-hour (kWh) and newly installed hydropower will cost between 1.5 and 8 cents/kWh, compared with 4 to 5 cents/kWh for nuclear power, 6 to 8 cents/kWh for power from coal, and 10 cents/kWh or more for electricity generated by combustion turbines.[2] By contrast, electricity from wind-power generators costs an estimated 6 to 15 cents/kWh, and electricity from photovoltaic cells an estimated 55 to 90 cents/kWh; however, these two renewable sources are still in the development stage.[3]

Shortages and price increases for fossil fuels, as well as environmental considerations, have made hydroelectricity increasingly attractive over the last 10 years and have led to a new interest in developing the Nation's hydropower potential. A recent survey by the U.S. Army Corps of Engineers indicates that the Nation's total hydroelectric power potential is almost 513,000 MW, over eight times existing capacity. The Corps suggests that installed capacity at the 1,251 existing facilities might be supplemented—perhaps by early in the next century—by almost 95,000 MW at 5,424 existing dam sites (either by adding more capacity or by installing generators at dams that do not currently produce electricity) and an additional 354,000 MW generated at 4,532 sites that do not yet have dam developments.

The Corps cautions that these figures are theoretical and perhaps overly optimistic: they do not balance the potential for power generation against the competing uses for dams, such as recreation, flood control, irrigation, and drinking water; nor do they take fully into account the engineering, economic, and environmental factors that would constrain the full development of this potential. For instance, about 75 percent of this additional capacity (over 338,000 MW) would come from undeveloped large-scale sites (25 MW or more) that the Corps itself estimates would operate less than 30 percent of the time. Construction costs at these undeveloped sites would be high, particularly compared to the expected returns for this low peak-load utilization, and it is doubtful that public utilities would be willing to invest in these large-scale developments even if they could find the capital to do so.[5] Furthermore, an extensive study of the environmental impacts of alternative sources of electricity generation indicates that new large-scale hydroelectric facilities are probably the worst choice, in terms of ecological damage, due for example to the flooding and loss of productive agricultural lands they will cause.[6]

The outlook for developing the Nation's small-scale hydropower potential is somewhat brighter. The 842 existing small-scale sites (under 15 MW)

[1] Paul A. Weinberger, "The Potential for Small-Scale Hydropower Development in the U.S.," *Energy* (Booz-Allen & Hamilton, Inc.), spring-summer 1980, p. 7.

[2] Donald B. Chubb, president, Safe Harbor (Pennsylvania) Water Power Corp., quoted by William J. Lanouette, "Rising Oil and Gas Prices Are Making Hydropower Look Better Every Day," *Natl J.*, Apr. 26, 1980, p. 685; Ronald A. Corso, director, Division of Licensed Projects, U.S. Federal Energy Regulatory Commission, quoted ibid., p. 686.

[3] Private communication from Lou Devine, Department of Energy, and the Solar Electric Corp., Rockville, Md. These cost calculations assume a capital recovery factor of 0.15, with varying estimates of capital costs and capacity factors.

[4] U. S. Army Corps of Engineers, *Preliminary Inventory of Hydropower Resources*, 6 vols., July 1979; the report is based in part on an earlier survey conducted by the Corps in 1977.

[5] George Grimes, engineering development program manager, Division of Small-Hydro Projects, Department of Energy, quoted by Lanouette, op. cit., p. 687.

[6] *Energy in Transition: 1985-2010*, final report of the National Academy of Sciences/Nuclear Regulatory Commission Committee on Nuclear and Alternative Energy Systems (San Francisco: W. H. Freeman, 1980), p. 476.

represent two-thirds of all U.S. hydropower sites but only 5 percent of the Nation's generating capacity, or about 3,200 MW. Estimates of the potential capacity of all small-scale sites range from 13,000 to 58,000 MW, although recent studies tend to favor the lower figure. About half of this potential is at existing dams. This includes dams where there are no generating facilities, where existing facilities can be upgraded, or where generating facilities have been abandoned due to the proliferation of large-scale power grids since World War 11.[7]

A small but significant boom in small-scale hydropower development is currently taking place. As a rule, investor-owned utilities have not been interested in small-scale hydropower projects, both because their capacities are too small to meet generating needs and because the high financing rates paid by utilities makes small-scale projects economically unattractive. A number of private entrepreneurs and industrial developers have applied for licenses to construct small-scale facilities, either as a business prospect or as an alternative to rising fuel and utility prices. But by far the largest category of small-scale hydropower developers, both now and in the foreseeable future, consists of municipalities, cooperatives, and irrigation districts. These developers are favored by Federal licensing requirements and have access to low-cost or tax-free capital for small-scale projects.[8] Over 40 municipalities have license applications pending at present, including such communities as Madison, Maine, Springfield, Vt., Saugerties, N. Y., Paterson, N.J., Martinsville, Va., Columbus, Ohio, Vanceburg, Ky., Muscatine, Iowa, New Roads, La., and Gonzalez, Tex.[9]

Small-scale hydropower cannot, by itself, significantly reduce the Nation's energy problems. It can, however, contribute to the share of the Nation's energy mix that is supplied by hydropower. The capital-intensive nature of hydroelectric projects (both large and small) means that financing costs have a major impact on the price of the power they produce, sometimes as much as 90 percent of energy costs,[10] but the energy they Produce is relatively immune to both inflation and rising fuel prices. For communities located near existing but undeveloped damsites, small-scale hydropower may represent an economically viable alternative that can address a number of local problems, including rising municipal energy costs.

This chapter examines small-scale municipal electricity generation by focusing on two communities in New England—Wareham, Mass., and Woonsocket, R.I.–that are planning to build small hydroelectric powerplants at existing damsites. Wareham is developing a 250-kW electric generating capacity at the Tremont Dam to produce power for sale to the local utility. Woonsocket plans a 1. 1-MW facility at the Woonsocket Falls Dam, which would generate enough electricity to supply 90 percent of the needs of the regional sewage and water treatment plants. These two projects present some interesting contrasts and similarities in planning and financing, as well as in technologies.

Wareham and Woonsocket are characteristic of the New England region in many ways. They have a pervasive sense of history and visible reminders of industries that once flourished. The abandoned factories are tangible symbols of the high unemployment, low incomes, and physical obsolescence in each town. Both communities also face rising energy costs because of their dependence on fossil fuels. The development of locally based solutions to these problems is important to the people of Wareham and Woonsocket because, like other New Englanders, they pride themselves on their "Yankee ingenuity" and a tradition of self-reliance.

[7]Weinberger, op. cit., p. 7.

[8]Ibid., pp. 8-9.

[9]Lanouette, op. cit., p. 689.

[10]Weinberger, op. cit., p. 9.

Small-Scale Hydroelectric Technology

Technology

Hydroelectric plants (see figure 34) transform the potential energy of the water into electrical energy in three basic steps: 1) water from a reservoir or diversion structure is carried through the penstock to a turbine; 2) the falling water turns the turbine, which is connected to a generator; and 3) the high-speed rotation of the generator coil generates electricity, which is then transmitted from the plant.

The water above a dam possesses potential energy because its level is higher than that of the water downstream. The amount of energy in the falling water is directly related to how many feet or meters it falls, a quantity called "hydraulic head."[11] The amount of power (energy per unit time) that can be extracted from the water is proportional to the head and the flow rate of the water.

Small-scale dams–those with a rated capacity of less than 25 MW[12]–are often referred to as "low head" dams, although they could be located on small but precipitous mountain streams that had high head but a low flow rate. New England streams, however, are large (high flow rate) but with a gradual drop, or low head (usually less than 66 ft).

Most large hydroelectric projects dam up a river and store water in a reservoir behind the dam. This allows the dam operator to buildup a supply of water when the river flow is at its peak and then release it when power is needed. Small-scale dams, on the other hand, are often operated "run of river." This means that all of the water flowing downstream at any given time will flow through the dam or over the spillway; virtually no pond or reservoir is created. Because a run-of-river dam does not store up a large amount of water, its power capacity varies with the changing flow rate of the river.

A user whose need for power fluctuates in the same manner is often difficult to find. In southern New England, for example, most electrical users have peak consumption during summer months, when they run their air conditioning, and low usage in the winter, when they heat their buildings with oil. Unfortunately, river flows tend to peak in the spring and are very low in the summer.[13] There are, however, several kinds of municipal loads that meet the constraints of run-of-river hydropower. One example is public schools, which have high usage from September to June when school is in session and virtually no usage in the summer. Another example is municipal street lighting, for which demand is high on long winter nights and low on shorter summer nights.

Economics

Water power played a major role in the early industrial development of New England, which is dotted with hundreds of old dams–nearly two-thirds of the existing but abandoned dams in the United States. The capital costs of installing a hydropower plant at one of these old river dams is

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[11] Actually, head consists of components due to the velocity and the static pressure of the water as well as its height, and is given by the Bernoulli Equation:

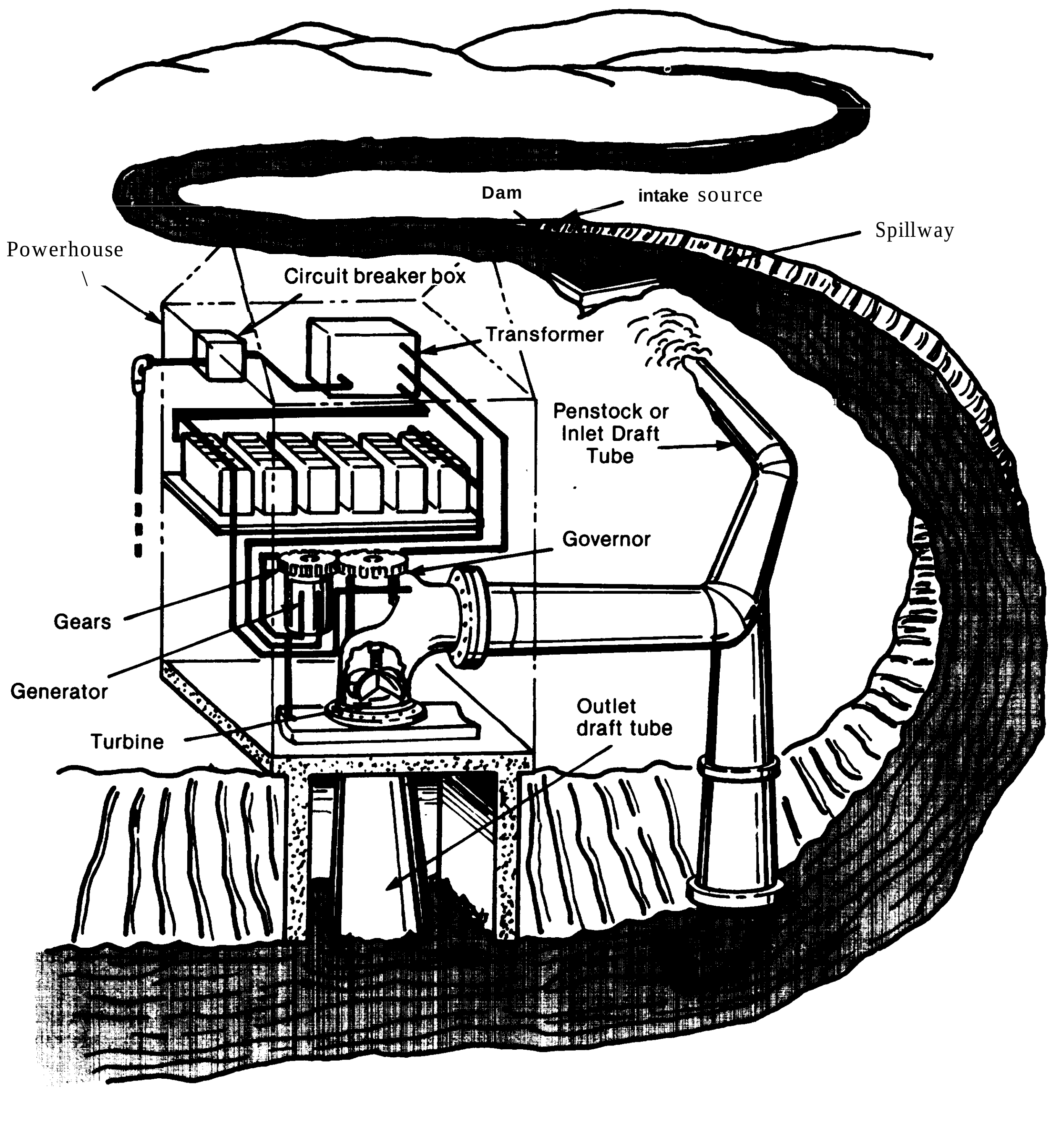
$$H = \frac{v^2}{2g} + \frac{p}{g} + y$$

where:
H = hydraulic head
v = water velocity
g = gravitational acceleration (32.2 ft/sec²)
p = static pressure
y = height water falls

[12] *Electric power* is the amount of energy used or produced per unit of time and is measured in watts, kilowatts (kW or 1,000 watts), megawatts (MW or 1,000 kW). Electric energy is the amount of power used over time, and is measured in watt-hours, kilowatt-hours, and megawatt-hours (Wh, kWh, MWh). For example, if you ran a 100-W light bulb for 10 hours, you would have used 1,000 Wh or 1 kWh of energy.

[13] The situation is more favorable in northern New England, where river flows are more uniform throughout the year and where there is less of an air conditioning load in the summer.

Figure 34.—Low Head Hydroelectric installation



SOURCE: Adapted from: Independent Power Developers' brochure "Hydroelectric Power". Adapted by: National Center for Appropriate Technology in Micro-Hydro Power (U.S. DOE).

high, however, since they involve feasibility studies, planning and design, and upgrading the civil works, as well as purchasing and installing the generating equipment. Low-head hydroturbines tend to have higher equipment costs per installed kilowatt of capacity than do high-head units.[14] Operating costs are lower, however, because the water is free and the dam requires little attention or maintenance.

By far the largest direct benefit of municipal low-head hydroelectric projects is the reduction of energy expenditures, but they also have important indirect benefits. Hydropower from existing small dams is an environmentally safe substitute for energy from more polluting sources, such as nuclear power, coal, and oil. Restoration of a small dam's civil works could also be a labor-intensive activity carried out by a public works job corps. The development of a local manufacturing industry for the retrofitting of low-head generating equipment could also stimulate the regional economy. Finally, the power produced by small-scale dams, if it can be sold at rates lower than those of local utilities, could be offered as an incentive for new industry to locate in the area, creating more new jobs and tax revenues.

[14]The expense has to do with the relationships between head, turbine diameter, and turbine speed. Given a constant flow rate, the turbine diameter required to extract a given amount of power from the water will increase quite rapidly as the head decreases.

A Case Study of the Tremont Dam Project, Wareham, Mass.

Community Setting

Wareham is a town of about' 16,000 people located in southeastern Massachusetts. Its economy is based on the shipbuilding, fishing, and tourist industries, and on the cranberry bogs which dot the landscape and provide seasonal employment at harvest time. The town, however, has been seriously affected by the industrial decline of the New Bedford-Fall River metropolitan area, of which it is part. The present unemployment rate is 15 percent or above—much higher than the rest of the State. To alleviate its problems, Wareham has initiated a program of economic development, including the creation of an industrial park to provide sites for new industry that will bolster its tax base.[15]

The Tremont Dam was orginally built by the Tremont Nail Works in 1845 as a source of power for its plant on the Weweantic River. It was operated from 1920 to 1938 by a shoe manufacturer, which sold electricity to the local utility company (a forerunner of the present New Bedford Gas & Edison Light (NBG&EL)) after its manufacturing operation moved south in the late 1920's. In 1938 much of the generating equipment was dismantled and moved with the shoe factory to South Carolina. In 1962, the Town of Wareham acquired the damsite, including water rights, pond, and 12 acres of land below the pond.

In the early 1970's, the Massachusetts Department of Public Works (DPW) issued several plans for the deteriorating Tremont Dam, which had become an eyesore. The last DPW plan, issued in 1974, called for demolishing the powerhouse and using the debris to permanently fill in the gates which controlled flow to the turbines. It was unclear whether any DPW money was forthcoming, however, and the Wareham Board of Selectmen asked the town's grants manager to investigate other possible sources of funding for restoration of the dam.

Interestingly, the early restoration plans were not focused on the dam's value as an energy project, but as an opportunity to provide temporary jobs for seasonally unemployed local construction workers. In 1975, Wareham secured a $400,000 Title X Public Works Job Opportunity matching grant form the U.S. Economic Development Administration to restore the dam, with the town putting up $100,000. The dam restoration occurred between February 1976 and July 1977, and a 1978 CETA Parks and Rivers grant paid for the

[15]Data and information on the history of the project come primarily from conversations with Bob Packard (grants manager) and John Healy (director of community development).

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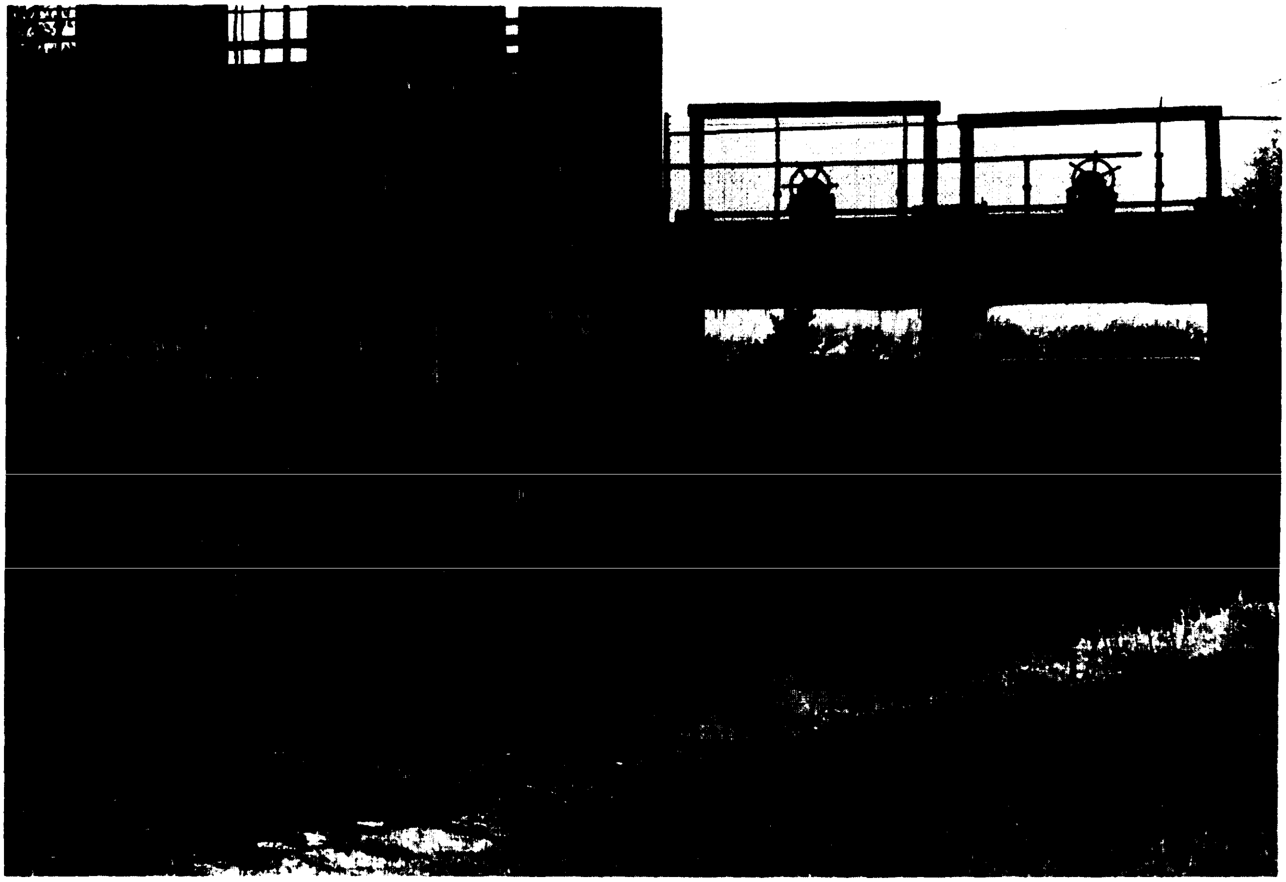

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clearing of the banks and riverbed below the dam and the building of a small recreation area.

Development

In 1978, the United Technologies Research Center of East Hartford, Corm., approached Wareham about applying for a study grant for the Tremont Dam under a Department of Energy (DOE) program to fund 54 feasibility studies of small-dam electricity production. A grant was awarded in mid-1978, and in February 1979 the study concluded that the site was feasible for power production. United Technologies also approached NBG&EL about the possibility of purchasing of power produced by the dam, and NBG&EL proved to be very interested in the project's potential public relations value: the company was moving its main office to Wareham, and involvement in the project would start its relationship with the town off on the right foot; in addition, the company had been criticized by local antinuclear groups, and participation in the hydropower project would demonstrate its commitment to environmentally benign power sources. [lb]

In August of 1979, Wareham received a $25,000 grant from the Massachusetts Office of Energy Resources for the purchase of turbines, but the town still needs an estimated $160,000 to complete the project. It rejected a grant from DOE that would have paid 15 percent of remaining costs and currently has an application before the Department of Labor for a 100-percent grant with which to purchase and install power generating equipment. (See *Critical Factors.*)

[16]NBG&EL is also participating in a solid-waste-burning powerplant (see ch. 7) and a windmill project, both within 10 miles of its new office in Wareham.

Equipment

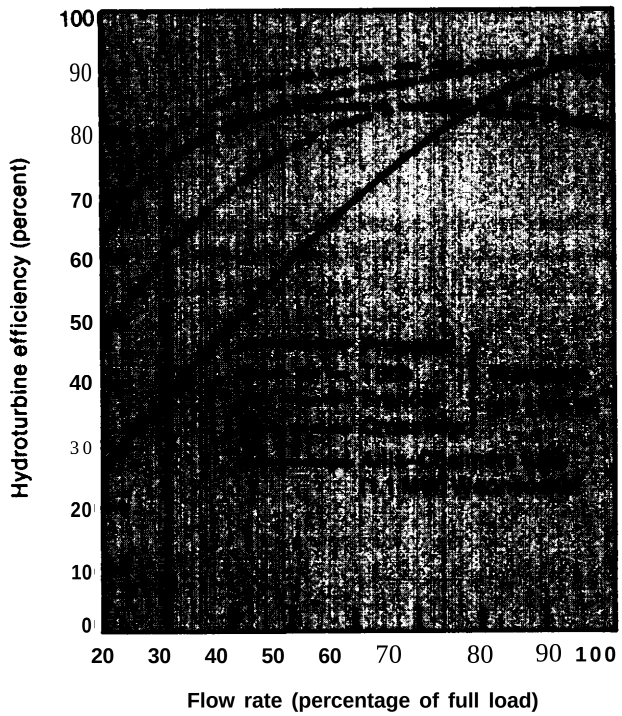
Very little additional work is needed to complete the whole project and begin producing electricity. The dam produces a hydraulic head of about 22 ft and could be developed economically to a capacity of 250 kW. The powerhouse is equipped with two elbow draft tubes which previously housed two Francis turbines. Although the draft tubes need to be replaced, the configuration will be retained and two vertical-axis turbines installed. Present plans are to install a modern 110-kW crossflow unit and a reconditioned 140-kW Francis turbine. [17]

The efficiency curves for the four turbine types that were considered for the Tremont Dam are presented in figure 35. The tube turbine has excellent partial-load efficiency and maximum efficiency, but for reasons that will be discussed later it would be infeasible at Tremont Dam. The propeller turbine has very poor partial-load efficiencies and it would, therefore, have been a poor choice for a dam that would experience seasonal drops in flow rate. The Francis turbine has modestly good partial-load efficiency and a maximum efficiency of over 80 percent. It will perform adequately in this site, but the major reason for choosing it was that the original units in the powerhouse were Francis turbines. It was felt that the project would have greater demonstration value if an older reconditioned unit could be run side-by-side with a newer unit.

The crossflow design was chosen for the modern unit because of its excellent partial-load efficiency, which is almost as good as the tube turbine's. This means that the efficiency of the equipment changes very little regardless of the flow rate, a highly desirable characteristic if the streamflow fluctuates greatly, as is the case in run-of-river hydropower projects. Some sacrifice in efficiency is experienced as the crossflow turbine approaches full load, but operation in conjunction with the Francis turbine will partially offset this deficiency.

[17] A complete discussion of the equipment proposed for the Tremont Dam can be found in E. S. Wright and J. J. Mankauskas, *Feasibility Study of the Tremont Dam Power Project*, United Technologies Research Center, February 1979.

Figure 35.—Hydroturbine Efficiency Curves[10]



SOURCE: Office of Technology Assessment.

Economics

Capital costs include $500,000 for restoring the dam and penstocks and $185,000 for purchasing and installing the turbines. The restoration costs are unusually high for a dam this size because the title X grant required a very high budget for labor; much of the work which could have been automated was not, in order to create jobs. Costs for feasibility studies, which should also be included, are in the neighborhood of $50,000. The total capital cost comes to $735,000, or $2,940 per installed kilowatt. An additional but probably insignificant cost is that of filing a licensing application. (Recent regulatory changes make available a simple and inexpensive—less than $500-procedure for obtaining an exemption from Federal licensing.)

First-year operating costs (excluding debt service) are projected to be $6,883. These costs include turbine and site maintenance ($0.004/kWh generated in the first year), depreciation, insurance (1.5 percent of turbine value), and any energy purchased to operate the automated gates. Debt service would also be an operating cost if Wareham had financed the project through a bond issue; dependence on grants, however, has created its own set of problems (see *Critical Factors,* below).

Revenue will accrue to the project from the sale of electricity to NBG&EL. Because the utility company refused to let Wareham lease its transmission lines, the town was prevented from using its hydropower directly for schools, street lighting, or other municipal purposes. Wareham will simply sell its power to the utility, which in turn will sell it back to the town at a higher price. While no rates have been agreed on, negotiations on first-year rates indicate a range of 2.6 to 3.0 cents/kWh. Strict comparison of these rates with present prices that NBG&EL charges the town would be inappropriate, since the NBG&EL charges also include a demand fee, fuel surcharges, and taxes, which may not be calculated on a per-kWh basis. Assuming that such a figure could be arrived at, it would probably be somewhat higher than the 2.6 to 3.0 cents/kWh rate offered by NBG&EL to the town, reflecting the utility's reluctance to give the town full credit for its power. Nevertheless, with an annual output of just over 1,000 MWh, this would yield revenues of $26,700 to $30,800, which would significantly reduce the town's electricity bill.[18]

Cash flow summaries prepared by United Technologies, assuming debt service at 7 percent for 30 years on the remaining $185,000 for turbine purchase and installation, indicate that first-year net revenue after debt service and all expenses would be $7,203. The cash flow assumes that operating costs will increase at a rate of 7 percent annually and fuel costs at 8 percent; however, both of these figures seem low, as does the spread between them, which suggests that revenues could be substantially higher. But using these assumptions, the project has an internal rate of return of 15 percent and a 10-year payback period. It must be pointed out again that this figure includes only about 25 percent of the real capital costs of the project; it excludes the $500,000 cost of dam restoration and another $50,000 for feasibility studies, both of which were financed with Federal grants (see above). If all costs are included, it would be difficult to say whether the project would be profitable at all; but by the same token, it would be difficult to put a dollar value on the benefits derived from increased employment or a new recreation area.

The project has already provided 70 full- and part-time jobs for dam restoration and the creation of the recreation area. It has no adverse environmental impacts, and the town hopes it will become an example of innovative technology that will attract local officials and visitors from all over the country.

[18]Wareham may receive substantially higher rates from NBG&EL when the State public utility commission implements the provisions of the Public Utility Regulatory Policies Act (see Federal Policy). For instance, under this Act the New Hampshire commission requires utilities to pay between 7.7 and 8.2 cents/kWh.

A Case Study of the Woonsocket Falls Dam Project, Woonsocket, R.I.

Community Setting

Woonsocket, R. I., is a city of 46,000 with pressing economic problems and low incomes. The city is dominated by the large brick and stone mills that were built along the edge of the Blackstone River in the 19th century to tap the available water power. These buildings are reminders of New England's industrial heritage, but although some of the mills are still in marginal use, the peak of activity has long since passed. Those who work in the mills consider $3.75 a high hourly wage, unemployment is severe, and one-third of the population has incomes below the poverty line.

The original dam at Woonsocket Falls stood until 1955, when it was destroyed by a flood. The present dam was begun in the same year by the

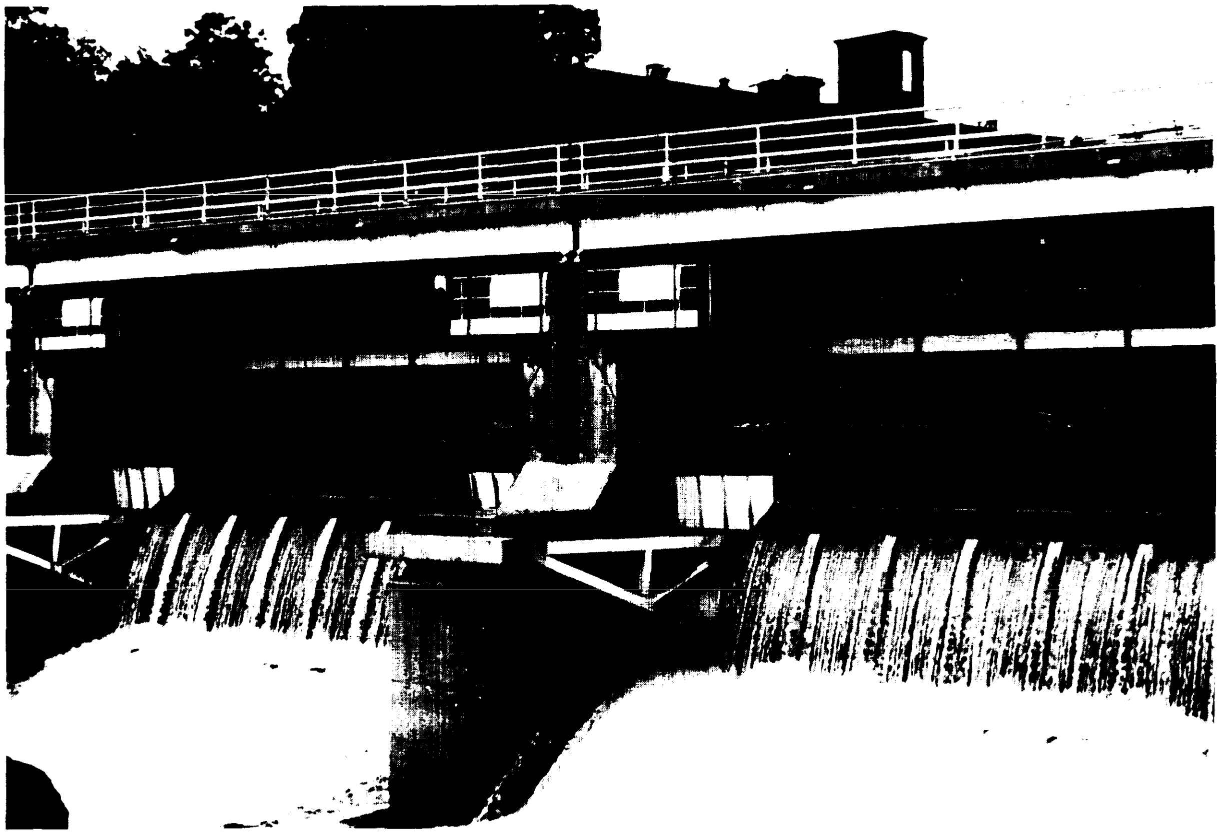


Photo credit: Office of Technology Assessment

Woonsocket Dam, Woonsocket, R.I.

U.S. Army Corps of Engineers as part of a local flood protection plan. The city now owns the dam and operates it according to Corps specifications.[19]

Proposals to build a municipal hydroelectric plant at the Falls date back to the 1960's. At the time, oil was cheap, there were no environmental regulations, and the citizens of Woonsocket did not take public power production seriously. The soaring price of energy since 1973 has changed their minds.

Development[20]

In 1978, the Governor's Energy Office urged the city to apply to DOE for a grant to study the feasibility of producing electricity at the dam, The $66,000 grant was awarded to a study group from the University of Rhode Island that also included State energy and environmental officials, city planning officials, and utility company representatives. The study was completed in January 1979, and after considerable debate the City Council approved the plan. In November 1979 the voters approved the bond issue for it by an overwhelming 95 percent majority. An update of the feasibility study has been completed, and the city has applied to DOE for a grant to cover 15 percent of the construction costs.

Equipment

The Woonsocket Falls Dam has a hydraulic head of only 18 ft, but because the dam is relatively new and well maintained it presents an excellent opportunity for hydropower development.

[19] Interviews with Joseph Anazer and Leo Millette of the U.S. Army Corps of Engineers.

[20] The history of current hydropower initiatives comes primarily from interviews with Joel Mathews and Marvel Valois of the city planning department.

The city has chosen a vacant lot 300 ft downstream of the dam as the powerhouse site, and it presently plans to develop the project to a capacity of 1.1 MW.

Two turbine configurations are under consideration, both manufactured by the Allis-Chalmers Co. The first is a standard 1.1-MW Kaplan tube turbine. Its efficiency curve (see figure 35) shows that to get any power at all from the unit, the turbine must operate above 30 percent of full load. However, above this lower limit the partial-load efficiency never drops below 75 percent, and maximum efficiency is above 90 percent; overall, this is a highly efficient unit.

The city is also considering a second configuration with two 550-kW turbine units. The advantage of having two units would be that, during periods when demand for power is low, one unit can be turned off and the other operated at full load for better efficiency. This is generally more economical than running both generators at partial load, because efficiency decreases under partial load conditions. For instance, a 25-percent total load would not run a 1. 1.1-MW unit, but would produce close to 90-percent efficiency in a single 550-kW unit.[21]

After considering several options, Woonsocket has decided to use the project to provide power for a regional sewage treatment plant and the city water works. The sewage treatment plant is less than 25 percent completed at present; when completed, it will have a peak demand of 4 MW and will obviously need power from another source as well.[22] However, at present it could absorb about 2,950,000 kWh from the hydroplane. The water works will consume about 2,760,000 kWh, or 79 percent of its energy needs. The city is currently negotiating an arrangement with Blackstone Valley Electric (BVE) to "wheel" power to these facilities over existing utility lines. (Wheeling is an arrangement whereby the city can transmit its power over the utility's lines through a rental agreement—an agreement that the power company in Wareham, Mass., refused to make.) The wheeling rate will be determined on the basis of the utility's equipment amortization: that is, a percentage of the capital costs of constructing the line.

Economics

Capital costs for restoring the dam, building the penstock and powerhouse, and purchasing and installing turbine equipment are projected at $2,682,950, or $2,439 per installed kW. The cost of the feasibility study, which was not included in any of the cash flow projections, was $66,000, or about $60 per kW. First-year operating costs are estimated at $40,885, including wheeling charges but excluding depreciation. Debt service is assumed to be $238,681 annually for a bond issue at 6-1/4 percent over 20 years.

Average annual energy production at the Woonsocket Falls Dam is estimated at about 6,570,000 kWh, of which about 87 percent will be consumed by the sewage treatment plant and water works. The surplus power would be sold back to BVE at day rates of 3.06 cents/kWh and night rates of 2.43 cents/kWh, for an annual city revenue of about $289,000.

Net revenue in the first year is projected at $9,556, reflecting all costs except the feasibility study. In following years, the city projects that costs will increase 9 percent annually, while revenues will increase with the price of energy at 13 percent annually.[23] No rate of return was given for the cash flow, but to give some idea of the profitability of the system, the projected net revenue for the twentieth year of the project is almost $2.5 million.

[21] Descriptions of the dam and proposed equipment can be found in John S. Krickorian, Jr., "Hydroelectric Power Potential, Woonsocket Falls Dam," University of Rhode Island Center for Energy Studies, January 1979; and John C. Halliwell, P. E., "Demonstration Project Proposal for Woonsocket Falls Dam," Halliwell Associates, Inc., Aug. 23, 1979. The Halliwell report also includes a cash-flow study.

[22] One reviewer suggested that this sewage plant, too, should be assessed for its appropriateness: "Why should sewage plants use so much electricity?" See ch. 8 for a discussion of alternatives for community wastewater treatment,

[23] Halliwell, op. cit., p. 14; rates of inflation are based on recent data from the Library of Congress, the Massachusetts Electric Co., and the Narragansett Electric Co. and are considered "moderately conservative."

Critical Factors

Public Perception and Participation

A survey showed that most local citizens were aware of the two hydropower projects and supported them, at least in principle. Most of those surveyed, however, had little detailed knowledge about the projects and were uncertain about their purposes. Many thought that the power should be used to deal with pressing local needs, and there was almost universal agreement that hydroelectricity and/or the revenue it provides should be used to reduce people's energy bills in some way. One common misconception was that the energy generated at the dams could be applied directly to space heating needs, despite the fact that heating requirements in that region are met largely by oil and some natural gas, not by electricity. In addition, many people overestimated the power-producing capacity of the projects; they spoke of generating enough electricity to meet the needs of all local residents or of all municipal services.

Local citizens in both Wareham and Woonsocket also expressed frustration with their local governments. They thought that they had not been provided with enough information to allow them to reach decisions intelligently, and often expressed irritation at the failure to hold town meetings where they could ask questions about the projects and discuss what they really meant for the communities. In addition, some residents said that a few influential people controlled the local decisionmaking process and that, as a result, these decisions did not always coincide with basic development needs. Despite these criticisms, however, the majority of those interviewed firmly agreed that hydropower is a valuable local resource, one that could provide significant benefits and deserves serious exploration.

Essential Resources

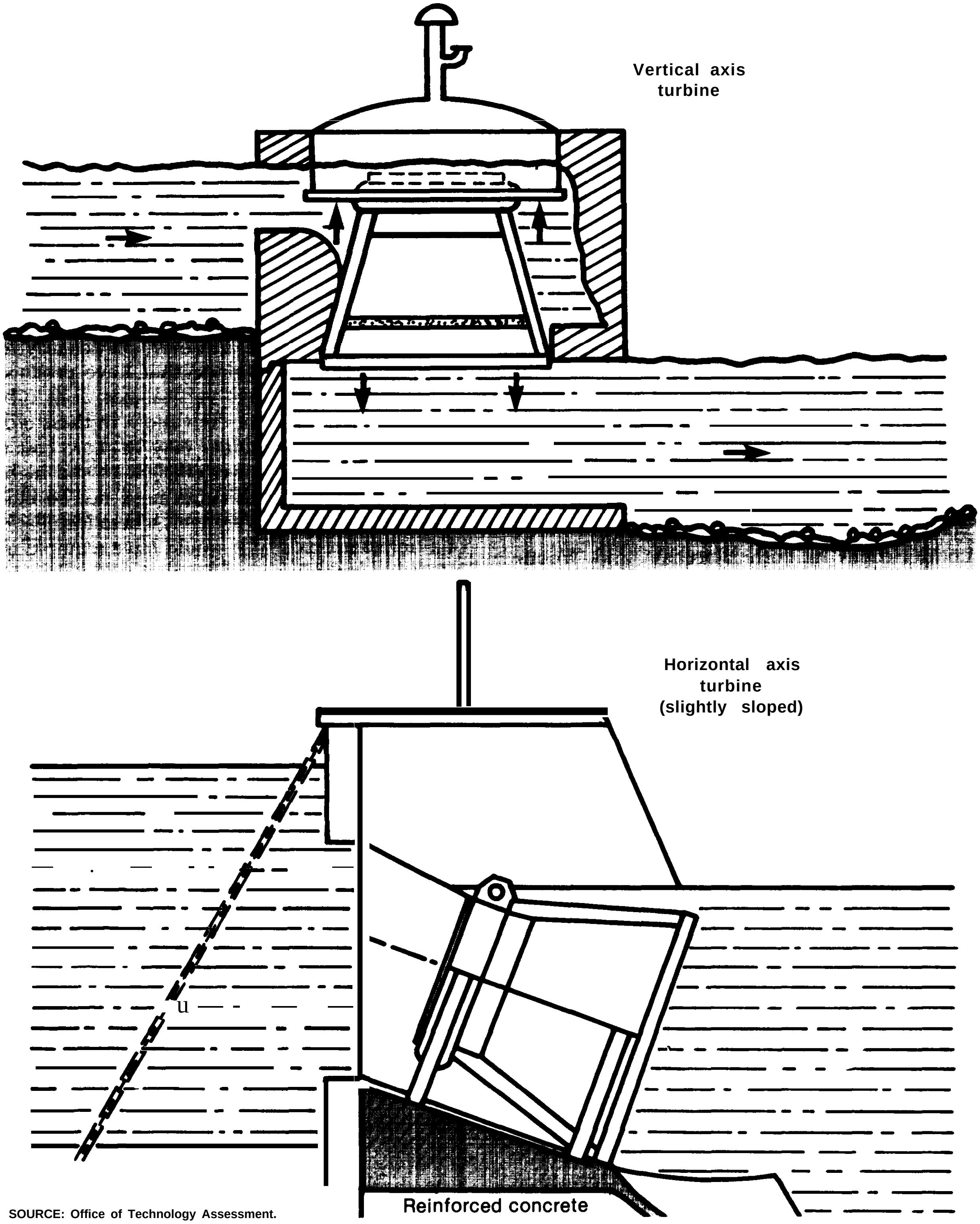
A potential constraint identified in these case studies concerns the availability of low-head turbine equipment. Hydroturbines can be broadly classified into two categories: those with vertically mounted shafts and those with horizontally mounted shafts (see figure 36). Vertical turbines were used frequently in New England in the early part of this century, and the two units most often utilized today are the Francis turbine and the propeller turbine. The horizontal or "tube" design, which was developed later, improves the efficiency of the system by permitting simpler draft tubes and smaller powerhouses. The resulting capital cost savings make the horizontal-axis turbine a logical choice when building a new powerplant or extensively modifying existing works.

Many existing dams, however, particularly the older ones in New England that have produced power in the past, have vertical-axis draft tubes that require little or no renovation. In these older dams, vertical-axis turbines may be more cost effective, despite their lower efficiencies and higher cost, because new draft tubes need not be built. This was the case in Wareham, where installation of a horizontal-axis tube would have required unjustifiably expensive modifications to the dam and works.

Unfortunately, there are few small-scale hydroelectric equipment manufacturers worldwide, and even fewer in the United States. When engineers in Woonsocket were looking at tube turbines, only one American manufacturer (Allis-Chalmers) produced a standard unit that met their specifications. (A second U.S. manufacturer—Tampella-Leffel-has recently entered the market.) The city also investigated the possibility of purchasing a reconditioned unit, but decided not to because of the limited experience of the firm. Several Japanese and West German firms produce a variety of tube turbines, but the city's construction grant from DOE indicated a preference for American-made equipment.

The situation in Wareham was somewhat different. The original equipment in the dam was two Francis turbines manufactured by an American firm. Fortunately, there are a large number of these units in abandoned small-scale hydroelectric

Figure 36.- Vertical and Horizontal Axis Turbines



SOURCE: Office of Technology Assessment.

plants all over the United States, and engineers located one that is compatible with the Tremont Dam site. Reconditioning these abandoned units could be a profitable business opportunity for some American firm.

The second turbine unit at Wareham will be a modern crossflow unit. Again, there are few American manufacturers of crossflow turbines, with the Bell Co. being the leader; worldwide, the largest manufacturer of crossflow equipment is the Ossberger Co. of West Germany. Wherever this turbine is purchased, however, it will have to be engineered to specification and will thus cost more. United Technologies favored customized turbines, arguing that flow and head conditions vary so widely from site to site that standard units usually result in less than optimal equipment.

Technical Information and Expertise

One of the most serious constraints on the development of a municipally owned small-scale hydropower project is the depth of engineering expertise required to implement the project. Because the small-scale hydropower industry went into decline earlier in this century, few engineering firms have experience in this field. Those that do have hydropower experience tend to be familiar only with large-scale systems and are either uninterested in the small returns from a small system or are unfamiliar with modern small-scale technologies.

One solution is to hire a consultant. Wareham has contracted with the research branch of United Technologies, a high-technology firm with little hydropower experience, feeling that the firm's lack of direct experience would make it less biased in the selection of equipment or manufacturer. (There are, however, several reputable consulting firms in New England that have both hydropower expertise and a reputation for providing reliable advice.) The original feasibility study for the Woonsocket Falls Dam was the effort of a team of faculty and students from the University of Rhode Island, working with a task force of State and local officials and representatives of the utility company. Dr. Krickorian, the study team leader, has developed a computer model which might be useful to other municipal officials in getting a rough estimate of the feasibility of the proposed hydropower project.

Another technical problem is evaluating the resource base; in the case of a hydropower project, this means compiling an accurate streamflow record. Because streamflow can vary substantially from day to day, month to month, and year to year, this record should consist of frequent readings over many years. The U.S. Geological Survey (USGS), which maintains gauging stations throughout the country, is often the best source of these records. For many damsites, however, historical streamflow data is unavailable, and the lack of this data at the outset can add substantial cost and uncertainty to the project. At the Tremont Dam, for instance, two estimates of streamflow were available, but neither was based on records obtained at the damsite: one estimate extrapolated data from a nearby river; the other used rainfall records and assumed runoff to estimate streamflow. When United Technologies took several months of streamflow measurements in 1978, neither estimate was found to correspond to the actual data. Instead, United Technologies examined all USGS records from gauging stations within 25 miles and a station whose hydrological conditions seem to approximate those at the Tremont Dam. Even after all of this effort, however, there is still uncertainty as to the accuracy of the data.

Financing

Energy generation projects require a variety of capital throughout their development. The first capital requirement involves funding a feasibility study and other preliminary planning. Feasibility studies for small-scale hydropower projects can be quite expensive because of the depth of engineering expertise they require: costs are typically between $30,000 and $75,000, and they seem to be unrelated to. the size of the project. This expenditure also entails a high level of risk, since there is no guarantee that the project will prove feasible or that the money will earn any return. Private enterprises routinely undertake this kind of risk, but municipalities do so only if the project is absolutely necessary, like new schools, or if it has the potential for considerable local benefits.

For this reason, some innovative projects will find it difficult to obtain municipal financing for feasibility studies, and another approach must be sought. DOE's hydropower study grant program, which funded 54 feasibility studies (including both Woonsocket and Wareham), is no longer available, but DOE has established a low-interest loan program in order to fund additional feasibility studies. The loans cover 90 percent of study costs and bear interest at 71/B percent over a 10-year term; however, no payments are due during the first 3 years of the loan, and if the project proves infeasible the loan will be forgiven. DOE and other agencies also perform "reconnaissance analysis," a quick and inexpensive evaluation of a damsite's potential, and the Corps of Engineers has issued a manual, Feasibility *Studies for Small-Scale Hydropower Additions*, which reportedly can be used even by those with little or no experience with hydropower.

By far the largest capital needs for a municipal energy project, however, come during the construction phase. At that point, since the project will presumably provide revenue after completion, debt financing becomes a reasonable option for the municipality. However, some communities (such as Wareham) still look for grant financing. This has several drawbacks. First, grants are often restricted in use and, as a result, several grants (from different agencies and for slightly different purposes) will have to be assembled in order to complete the project. This creates delays and financial insecurity, since projects can be left half-finished if one grant doesn't come through. Restricted-use grants, like the title X funds for the Tremont Dam, can also cause the project to be much more labor intensive than necessary and thereby drive the total cost of the project up.

Another characteristic of grant financing is that few grant programs will cover the total cost of the project. Wareham's title X grant provided 80 percent of the cost of restoring the dam, with the city putting up $100,000. For the purchase of turbines, Wareham received a $25,000 grant from the Massachusetts Office of Energy Resources and planned to apply to DOE for the remaining $160,000. The city found, however, that DOE would only cover 15 percent ($27,500) of these costs. DOE feels that debt capital is available for these projects and hopes the communities will use the 15-percent grants as seed money to attract private capital. (For rural communities, funds may be available through the Rural Electrification Administration.)

Woonsocket has approached construction financing differently and has been able to proceed much more rapidly. Total project costs are estimated at $2.68 million, but cash flow projections are very favorable and for this reason the city has received permission from both the State of Rhode Island and its own residents to raise the construction capital through the sale of general obligation bonds. (Unlike Wareham, Woonsocket also applied for the 15-percent construction grant from DOE.) Because the project shows a profit, after debt service, every year over the life of the loan, it looks like a good candidate for revenue bonding. But the profit margin in the project's early years may be too tight to count on, and the cash flow projections include assumptions about capital costs and energy price increases which might not prove accurate.[24] In view of these problems, general obligation bonds appear to be a safer approach.

Although Woonsocket city officials appear confident in their ability to sell their bonds, they must first obtain a firm commitment from BVEC on wheeling charges and buyback rates, and this agreement must specify conditions for future price increases. DOE has encouraged projects that do not show a profit after debt service in early years to offer their power to local utilities at a flat rate that does not increase over time. A utility may be willing to pay a price that is higher than present replacement costs if it is assured that the price will not rise in the future, this would give the municipality sufficient revenue in early years to cover

[24] An example of this problem faces Woonsocket at present. It was initially believed that power from a recently completed facility in Quebec would be available to BVE at rates lower than the cost of producing that power at oil-fired powerplants. Recent projections indicate that although the Quebec project could provide a more stable source of energy than foreign oil supplies, its cost will not differ greatly. However, instabilit, in world oil markets has affected projected revenues to the project so dramatically that the project may ultimately be restructured entirely. Increasing oil prices have increased the buyback rates the utility company is willing to pay for power purchased from the dam so greatly that the cit, now wishes to wheel smaller amounts of power to its two electricall, heated schools (both of which have more favorable demand profiles given the load profile for the dam) and sell more power to BVE. Updated cash flow summaries for this option were not available for inclusion in this assessment.

debt service on a revenue bond issue. Unfortunately, this approach denies the municipality the full value of its power, and local utility companies justly fear that if fuel prices continue to rise as rapidly as they have in the past, a flat-rate deal would be a politically untenable arrangement. In general, the municipality will derive the greatest value from the power it generates if it uses it to satisfy its own energy needs, rather than selling it to a utility. This problem may be resolved by the implementation of the Public Utilities Regulatory Policies Act in early 1981 (see Federal Policy).

Institutional Factors

Unless energy generated at a hydroelectric plant is to be used onsite, it must be transmitted to its point of use. Because transmission lines represent a large additional investment, most municipalities (like Wareham and Woonsocket) will probably either seek wheeling arrangements with local public utilities or sell their power to the utilities. The utility companies, however, are reluctant to wheel power, first because they lose revenue when customers drop electric service, and second because it is difficult to determine a fair wheeling rate, since there is no precedent for this service and it is not regulated by public utility commissions. In the future, with increasing numbers of small power producers, wheeling may become a more common and standardized process; but whether the majority of utility companies would be receptive to such a situation is questionable. The State of New Hampshire is considering legislation that would set wheeling rates and force utility companies to comply, and Congress has recently enacted legislation that deals with this issue (see below).

Federal Policy

Background

Water power became the primary source of energy for American industry in the early 19th century, and, because there were few restrictions, the development of this energy source was relatively simple for the growing manufacturing economy. It presented problems, however, for future use of water resources by other sectors, particularly agriculture. Public policy regarding hydropower evolved, therefore, from a desire to ensure that such development on navigable streams was in the public interest of a growing Nation with diverse and growing needs.

A fear of private monopoly and the loss of public control of a vital natural resource prompted congressional action to slow private development in the early 1900's. The policy of Government control through licensing was embodied in the Federal Power Act of 1920, which established the Federal Power Commission to issue licenses for the construction, operation, and maintenance of dams, reservoirs, powerhouses, and transmission lines. A series of laws enacted between 1920 and 1950 increased Federal involvement in the development and operation of hydropower facilities and the sale of hydropower. These laws included amendments to the Federal Power Act, the Boulder Canyon Act of 1928, the Tennessee Valley Authority Act of 1933, the Public Utility Act of 1935, the Bonneville Act of 1937, and the Flood Control Acts of 1936, 1938, and 1944. Today, a complex set of rules, regulations, and institutions govern the development of hydroelectric power.

The rise of the environmental movement and the demand for more efficient Government operations led to attempts during the 1960's and 1970's to integrate water resource activities into a comprehensive package of resource development and conservation. This effort was guided by the passage of such legislation as the Wilderness Act of 1964, the Water Resources Planning Act of 1965, the Wild and Scenic Rivers Act of 1968, and the National Environmental Policy Act of 1969.

Small-Scale Hydropower Programs

Until the 1970's, most people thought of hydropower as big dams and large-scale generating facilities. Shortages of fuel and other resources, rapid increases in oil and gas prices, the 1973 Arab oil embargo, and mounting pressure from environmentalists have led to increased interest in alternative forms of hydropower, including the restoration of existing small-scale dams and hydroelectric equipment.

By itself, small-scale hydropower cannot significantly relieve the Nation's energy problems. The Federal Energy Regulatory Commission (FERC) estimates that the undeveloped hydroelectric potential at existing dams with a capacity of less than 5 MW would total no more than 26,600 MW. Nevertheless, this represents a savings of 139 million bbl of oil,[25] or about 3 weeks' imports at current rates. Because energy generated at small-scale hydropower sites is immune to rising fuel costs, it will also be increasingly competitive with other sources of electricity. For communities located near existing but unused hydropower sites, therefore, small-scale hydropower may represent an economically viable alternative that can help in addressing a wide range of local problems, including rising municipal energy costs.

President Carter publicly recognized the potential for small-scale hydropower projects in 1977, and Congress took an active role in the promotion of these projects by appropriating an initial $10 million to establish a small-scale hydropower program in DOE. Since then, the DOE demonstration grants program has funded $50 million in studies and construction, and funding is also available through other programs in the Departments of Energy, Agriculture, Labor, and Commerce, as well as the Community Services Administration (CSA).

Major legislation that affects small-scale hydropower projects includes the following:

- *Federal Power Act of* **1920** (41 Stat. 1063), as *Amended in* 1935.—This law contains a provision (sec. 7A) which, according to some critics, may discourage private development of small-scale hydropower. Section 7A concerns competing applications: under its provisions, a public body such as a municipality will be granted preference over a private developer in securing the licenses for a hydropower site, regardless of the order in which the applications are submitted and regardless of the capital already invested in the site by the private developer. For example, a private developer who had developed and operated a site under Federal license for a period of years might still lose license at the time of renewal, if a public body chooses to apply for a license to operate the same site.
- *Public Utilities Regulatory Policies Act of 1978 (Public Law* 95-617).–This law streamlines the licensing process for small-scale hydropower projects; provides cost-sharing funds for feasibility studies, for license application costs, and for architectural, engineering and construction costs; declares them not to be utilities and therefore exempt from local utility commissions; and requires local utilities to allow them to use their power grids and to purchase power from them at rates to be set by State utility commissions by February 1981.
- *Energy Security Act of* **1980** (Public Law 96-294) V-This law further streamlines the licensing process for small-scale hydropower by exempting projects under 5 MW from FERC licensing. This exemption does not extend to review and processing by other Federal agencies, however, and some procedural problems remain. (See the discussion of this issue below.)

Major legislation introduced in the 96th Congress includes amendments to the Internal Revenue Code to provide tax credits for equipment used at small dams to produce hydroelectric power, to extend tax-free financing, and to make small-scale hydroelectric property eligible for residential energy credits. Other proposed bills cover items such as a trust fund for R&D in alternative energy resources, increases in funds for feasibility studies, provisions for surveying and other technical assistance, provisions for construction of small hydroelectric projects not specifically authorized by Congress, permission for Federal agencies to enter into agreements with States to avoid duplication of and delay in licensing procedures, and changes in the definition of small-scale hydropower.[26]

[25] Mary M. Allen, "A Report on the Potential Use of Small Dams to Produce Power for Low-Income Communities," prepared for the Community Services Administration, contract report No. B8B-5584, Aug. 4, 1978, p. 1-15.

[26] Warren Viessman, Jr., and Christine DeMoncada, "Water Resources: Small-Scale Hydroelectric Power, " Library of Congress,

Issues and Options

ISSUE 1:

Coordination of, and Community Access to, Federal Assistance Programs.

Despite the number and variety of Federal programs for small-scale hydropower projects, there are complaints about the adequacy and coordination of Federal assistance. These problems have to do with the definitions and objectives of the programs themselves, the application procedures for licensing and financing, the regulatory structure for public utility rates and wheeling arrangements.

One difficulty arises from confusion over what exactly constitutes a "small scale" hydropower project. DOE, for instance, defines a small-scale project as a site with a head of less than 66 ft and a power potential of between 50 and 15,000 kW. The Corps of Engineers, on the other hand, defines small dams as structures less than 40 ft in height with a potential capacity of less than 5,000 kW.[27] As a result, a project may be eligible for funding under one program's small-scale criteria, but not another's. Because the funding from a single program rarely covers the total cost of any given project, multiple sources will usually be required, as was the case in both of the projects studied in this chapter. Consequently, these differing sets of criteria complicate the application process, increase the time and expense involved, and may in some cases bring the project to an impasse.

A related problem has to do with the differing objectives of the various Federal small-scale hydropower programs. Often these programs dictate the objectives of the grant and the uses to which the funds can be put, but these requirements differ from act to act, from agency to agency, and from program to program. These requirements can sometimes conflict with one another or with the objectives of the local community, and these conflicts can distort the results of a project or increase its costs. For instance, the grant for the Tremont Dam project in Wareham specified how much of the money should be used for jobs and how much for materials. As a result, the project was far more labor intensive than necessary, and it probably cost both Wareham and the Federal Government more than it should have.

A similar complaint concerns the burden placed on the limited resources of small communities by the complicated and time-consuming procedures for obtaining permits and licenses for hydropower projects. Statutes that affect the licensing process include the National Environmental Policy Act, Fish and Wildlife Coordination Act, Endangered Species Act, Historic Preservation Act, Water Pollution Control Act, Water Quality Improvement Act, Wilderness Act, Wild and Scenic Rivers Act, Coastal Zone Management Act, and Federal Land Policy and Management Act. FERC licenses all non-Federal development on Federal lands or navigable rivers that affect interstate commerce, but the Commission's jurisdiction has been defined so broadly by the courts that it covers virtually all hydropower projects.[28] FERC introduced new application and licensing procedures in 1978 to reduce paperwork and accelerate approval for projects under 1.5 MW,[29] and these procedures were further streamlined by the Energy Security Act of 1980, which authorized FERC to exempt hydropower projects under 5 MW from licensing.

This exemption will not necessarily ease the regulatory burden, however, because small-scale projects still remain subject to review by agencies other than FERC. According to one official, it does little good to require one of the agencies—i.e., FERC—to streamline its review and licensing procedures unless the remaining agencies are also required to do so.[30] For example, the Corps of Engineers has jurisdiction over all navigable rivers, including changes to the streambanks, streambeds, or streamflows. As with FERC, legal rulings give the Corps control over even the smallest streams; but many interpretations and rulings are left to the Corps' regional offices, and some differences re-

Congressional Research Service, issue brief No. IB 78035, May 12, 1980, pp. 4-7; Wendy H. Schacht, "Appropriate Technology: Alternative Domestic Technologies, " Library of Congress, Congressional Research Service, issue brief No. [B 77090, Jan. 13, 1980, pp. 8-10.

[27] Allen, op. cit., p. 112.

[28] Ibid., p. V-5.

[29] Viessman and DeMoncada, op. Cit., p. 4.

[30] Ronald A. Corso, Division of Hydropower Licensing, Federal Energy Regulatory Commission, personal communication, July 30, 1980.

portedly exist among these offices.[31] Special reports and consultations are also required by different bureaus within the Department of the Interior, the Advisory Council on Historic Preservation and State historic preservation offices, and the Department of Agriculture.

When conflicts arise in the above procedures, hearings are sometimes necessary, which entail more expense and time and may lead to long delays. Even without conflicts, however, the substantial amount of manpower and legwork involved in obtaining financing, licenses, and regulatory permits is a burden on small communities and a serious barrier to the implementation of their projects.

Option 1-A: Designate a Central Clearinghouse for Information on Low-Head Hydropower.—At present there is no central location to which communities can go for information on the various Federal programs, their objectives and their eligibility criteria. Communities seeking aid would be helped immensely by having a compendium of these programs, regulations, and requirements readily available. The National Center for Appropriate Technology, the Library of Congress, or the agricultural and energy extension services might be logical clearinghouses for such information. Technical data, which is also needed by interested communities, might also be distributed through the same outlet.

Option l-B: Establish Agreed-On Definition of Smal1-Scale Hydropower and Further Streamline Licensing Process.—In view of the confusion created by the different definitions of "small scale" hydropower employed by various Federal agencies, it would be useful if some organization, such as DOE or the Corps of Engineers, were to devise a standard definition of small-scale hydropower; this would simplify data collection and aid in the licensing process. While some effort already has been expended to streamline these procedures, it appears to be taking place on an agency-by-agency basis. It may be helpful for Congress to review the total licensing process with an eye toward bringing about a more coordinated and thorough streamlining of the process.

ISSUE 2:
Technical Assistance.

As discussed above, municipal hydropower projects require a considerable range and depth of technical expertise, particularly in the evaluation and planning stages. This expertise is often beyond the resources of a small community.

Option z: Make Technical Assistance More Accessible to Local Governments.– The Corps of Engineers has conducted a comprehensive survey of potential hydroelectric sites and has also issued a guidebook for simplified feasibility studies at small-scale sites. USGS could assist municipalities in evaluating their resource base by preparing estimates of average monthly streamflow at existing damsites. FERC has prepared manuals for local officials on how to plan, develop, and manage a small-scale hydropower project; similar efforts have also been undertaken by the Corps, DOE, and CSA. Widespread dissemination of these planning aids to State and local governments might encourage additional projects by making the first steps in a community hydropower development simpler and less risky. A seminar program for engineering professionals from both the public and private sectors would be useful in disseminating information, in focusing on new developments in the field, in encouraging conventional engineering and consulting firms to enter the field, and in establishing a network of contacts between communities and between sectors.

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31 Ron Alward, Sherry Eisenbart, and John Volkman, "Micro-Hydro Power: Reviewing an Old Concept," prepared by National Center for Appropriate Technology for Department of Energy, report No. ET-78-S-07- 1752, Jan. 1, 1980, p. 47.