To give only one instance of depletion, the United States has already consumed about half of its own oil, once one of the largest reserves in the world. . . . The simple solution is to put your power station next to a factory or in an urban area. The waste heat can then be piped to nearby buildings or used for process heat in factories. A company might even have its own power station providing both heat and electricity—the so-called cogeneration unit. What was formerly regarded as waste heat is now used for process heat or district heating, enormously increasing the efficiency with which the fuel is used.

Barbara Ward

*Progress for a Small Planet* (1979)
New York City in the Blizzard of '88: Power lines fell, transport halted, the city was paralyzed. But one service continued without interruption. District heating steam service in Manhattan carried on without a pause straight through the storm (courtesy of the Museum of the City of New York).
COGENERATION AND DISTRICT HEATING

An Energy-Efficiency Partnership

by Roy Meador
Science Writer
Ann Arbor, Michigan
Cogeneration and District Heating reports on a traditional energy technology that has an important new assignment: Getting maximum energy benefit from every type of fuel. This revived technology could help American utilities, industries, and consumers more than double fuel efficiency in the decades ahead. The proven methodologies of cogeneration and district heating have been widely used in Europe since World War II, and many lessons have been learned that will benefit development in the United States.

Despite its success in Europe during the past quarter-century, district heating is not an European invention. It began, strangely enough, in the home of a versatile American inventor named Birdsill Holly during the year 1877 at Lockport, New York.

This book covers the early history of district heating, gradual development of cogeneration, and establishment of the first district heating service in New York City (steam deliveries have been continuous there since 1882). The quick rise and subsequent decline of the technology in the United States because of plentiful, low-cost fuel and because of changing lifestyles are fully explored.

Cogeneration and district heating are technically explained in the book. In simplest terms, cogeneration involves combined production of electricity and heat energy. When cogeneration is added to the operations of an electric utility, the plant’s fuel efficiency may increase from 33% as high as 80%. The book ex-
plains how and why. By more than doubling fuel efficiency, the result could be likened to the effect of lifting your automobile's efficiency from about 30 miles per gallon of gasoline to over 60 miles per gallon. As fuel costs go up, your savings would rapidly soar. In the case of electric and heat production, the savings through cogeneration can amount to billions of dollars.

A district heating system, described simply, conveys hot water or steam for heating (and cooling) from a central power source through pipes to consumers. Transmission lines carry the heating medium from the central station to the service area, where distribution lines branch off and deliver heat to individual locations.

The rationale for district heating during the 1980s and beyond is covered at length in the book. Three main reasons stand out: (1) district heating produced through cogeneration conserves fuel by increasing efficiency, (2) significant environmental benefits, (3) lower costs for heat than consumers may pay when they generate heat for themselves by burning fuel.

The reasons Europe generally adopted district heating while the United States made little progress with the technology are considered. Also explored are the primary use of hot water district heating in Europe and the U.S. preference for steam district heating. The performance advantages of hot water are examined.

District heating and cogeneration are discussed in the context of contemporary users worldwide. The specific programs and systems of Consolidated Edison Company of New York, Detroit Edison, Dow Chemical Company, Consumers Power Company, and others are analyzed to show the versatility, problems, and prospects of the technology for various regions in America.

The book explains why district heating and cogeneration have renewed value in the United States as reserves of the fossil fuels—oil, natural gas—decline and prices climb.

Energy logic and frugality, fuel sense, and purse wisdom prescribe that the energy future of the United States should include this 19th century technology on a wide, expanding scale. This is a century-old way to get the most from fuel. Its time has
come again, because energy-saving is necessary once again as a long and cheerful era of gluttonous energy consumption approaches its inevitable, painful end. Cogeneration and district heating may help limit the pain.

This book details what is now being done to revive the technology in the United States. Prospective and current projects are described. Several American communities, organizations, and companies have learned or been reminded that cogeneration and district heating stretch available fuel as far as possible. This means fuel conserved and funds not spent. Some are acting on the discovery.

The point is made that virtually any alternative fuel is readily adaptable to this remarkably flexible technology. Any power source is functional if it can deliver steam or hot water. Cities around the world are swiftly investing in farsighted and fore­sighted programs to derive electricity and district heat from municipal refuse. Recycling waste material to heat the homes of those who produce the waste is a continuing form of energy sanity that district heating resourcefully assists. This movement is discussed.

The truth is stressed that now is the time to begin doing something about the cogeneration-district heating opportunity. The book concludes: "Looking back in 20 years, some will be glad they acted, others will wish they had."

The fact this technology is an inheritance from the 1880s makes it all the more intriguing to energy watchers and planners with cautious eyes glued to the future.

Roy Meador
Ann Arbor, Michigan
April 1981
Acknowledgments

Science and technical writing assignments from the Michigan Energy and Resource Research Association (MERRA) and from the U.S. Department of Energy introduced me to the fascinating and promising energy fields of district heating and cogeneration.

Special thanks are due Todd Anuskiewicz, MERRA Research Director, who conceived and coordinated district heating conferences, publications, workshops, discussions, and related activities. These have contributed substantially to keep the option of district heating alive and well in the United States. Without his leadership and drive, more people would be saying “what’s that?” rather than “let’s go!” to the idea of district heating.

District heating is not yet a subject one can learn enough about at the library. It is a subject public officials and the public need to know. I am grateful for information, assistance, and support I received from district heating activists in St. Paul, Minnesota; Jacksonville, Florida; Bellingham, Washington; Detroit and Midland, Michigan; New York City; Washington D.C.; and the Argonne National Laboratory; as well as uncounted additional sites around the country. District heating may still be a concept looking for homes in the U.S., but it is looking many places.
For Helen Meador who daily demonstrates that midnight oil is the prime fuel of productive research.
Roy Meador is an Ann Arbor, Michigan–based freelance writer, specializing in technical and scientific subjects. He has written extensively for government clients and U.S. corporations, including Gelman Sciences, General Motors and Pfizer, Inc.

In 1978 Mr. Meador completed a writing assignment on earth-scanning satellites for the National Aeronautics and Space Administration (NASA). In 1980 he compiled a report on gasohol for the state of Michigan. In 1981 he wrote a report about district heating for the Argonne National Laboratory and the U.S. Department of Energy.

Mr. Meador has written on a wide range of subjects for the Michigan Energy and Resource Research Association (MERRA). Topics include energy conservation, wind energy, peat, small hydro, coal pulverization, coal-oil mixtures, resource recovery and nuclear cogeneration. Reports on solar collectors and wind turbine generators for the Central Solar Energy Research Corporation were among his 1981 projects.

The author graduated from the University of Southern California and received a master’s degree from Columbia University. He served as an officer in the U.S. Navy aboard a Destroyer Escort during the Korean War.

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"I don’t want to wait for district heating until St. Paul is freezing," said George Latimer, Mayor of St. Paul, Minnesota, in 1980. [1]

St. Paul is one among several American cities pushing ahead with district heating developments based on cogeneration. The prime appeal of the technology is an opportunity to utilize thermal energy that otherwise might be wasted by an electric utility or other power generating source. The historical practice of dissipating waste heat into the surrounding environment is replaced by the more practical method of distributing the heat in the form of steam or hot water through pipes to residential, commercial, or industrial users.

Approximately 20% of U.S. energy use is for heating and cooling applications. An estimated half of this energy, or 10% of the nation’s total consumption, could be supplied through cogeneration and district heating systems.

District heating was first used in America over a 100 years ago when steam service was offered at Lockport, New York in 1877. New York City has benefited from a continuous district heating operation nearly a century.

The point is that this is not a new, but rather an established technology that declined during the 20th century in the United
States because fuel was cheap and there was no apparent or accepted need for conservation.

“Times change, and we change with them” says a Latin proverb. Citizens in the 1980s will recognize its relevance to the energy situation as fuel prices rise and supplies decrease. District heating through cogeneration is once more a useful answer to a human need.

Thomas E. Stelson, Assistant Secretary for Conservation and Solar Energy in the U.S. Department of Energy, stated the following in 1980: “District heating is an essential component of our national strategy to conserve scarce fuels. It is an effective method of reducing fuel consumption, improving urban air quality, providing strategic space heating options that free us from dependence on a single fuel source, and reducing the rate of energy cost increases. For many reasons district heating is an idea whose time has come again.” [1]

“Isn’t it better to invest in district heating and get some of our investment back than to keep spending on energy with no prospect of return?” asked Delbert Anderson, former member of the Minnesota House of Representatives and an advisor on district heating. Hans Nyman, experienced in European district heating operations, observed, “When we started district heating programs in Europe, we had the same problems you’re facing here. The problems can be solved. District heating can save money and fuel here as well as there. Don’t forget your coal. Look to the future.” [1]

Looking to the future means emphasizing an energy technology that could both warm and cool American cities, neighborhoods, and business or institutional developments during the remainder of the 20th century and into the 21st century. Just as cogeneration and district heating have grown in Europe, they could grow, with substantial energy-saving benefits, when they are understood and forcefully implemented in the United States by industrialists, businessmen, energy managers, homeowners, city councils, state legislatures, and the federal government. The collaborative efforts of all concerned will be needed to promote the costly and large-scale developments involved. Echo-
ing Mayor Latimer, hopefully the developments will take place before St. Paul and other cities freeze.

Despite the long history of district heating and cogeneration, relatively little modern literature covers the subject. Technical papers, journal articles, European publications, company and government reports are the main published sources for this overview of the technology. The following chapters focus on what district heating is and why through cogeneration it is an important energy opportunity. Decisionmakers, energy managers, and citizens generally need the information because too little is known about this energy method that offers a valuable new option.

Consider the versatility: Coal is one means of transmitting heat through pipes. Steam or hot water as well as electricity can also be produced by burning urban refuse. Oil, natural gas, coal, wood, peat, nuclear fission, biomass—each can be used for cogeneration. Each is used somewhere in the world. Solar energy in one or all of its many forms can be used eventually to deliver power and heat.

Assembling material for this book, the author toured a nuclear power plant under construction at Midland, Michigan. This plant in the 1980s is expected to become one of the largest cogeneration and district heating operations in the world, capable of producing about 1300 megawatts of electricity and approximately 4 million pounds of steam per hour. The Midland activity emphasizes the adaptability and scope of cogeneration and district heating technology.

When district heating cogeneration is retrofitted in electric power plant operations, fuel efficiency increases from about 33% (electricity only) to over 60% (electricity plus thermal energy). Once it is widely used in the United States, district heating will replace oil or natural gas combustion in home furnaces. This will significantly help achieve the national goal of conserving scarce fuels. [2]

“It is foolish to wait until you have to act,” said Mayor Latimer. “I am of the definite opinion the people are tired to death of overcautious politicians.” [3]
Cogeneration and district heating information should assist students, managers, businessmen, industrialists, politicians, and others who recognize the necessity of using available energy competently. District heating, of course, is not a cure-all for chronic energy woes. But the technology supplies an effective way to improve energy consumption habits.

It may be time to stop kidding ourselves that there will be one comprehensive, all-embracing, all-purpose energy solution. Each energy option—solar, biomass, fission, fusion, coal, geothermal, hydro, refuse—should contribute to the world’s future energy audit. No single alternative is likely to take charge and dominate.

District heating through cogeneration can be a steady contributor, working in partnership with most of the energy options now juggled anxiously by the experts.

There is a drawback naturally, or many American homes would already be using district heating. The drawback is cost. The cost of development is high because laying steam or hot water pipes is a major capital expense. Yet, in spite of heavy startup costs, the consensus is that district heating projects in the United States, even large ones, can pay for themselves. This book looks at the economic prospects for district heating.

Todd Anuskiewicz, Research Director of the Michigan Energy and Resource Research Association, said in 1980, “District heating is a C.O.D. package of enticing possibilities—using waste energy, saving fuel, purer air to breathe, energy deliveries to industry, jobs and reliable heating service for low-income city dwellers. The hitch is the price before we can open the package. But since the cost is likely to go higher, now’s the time to start.” [1]

A direction is needed and a chart. Even Columbus had a direction. He would sail west and see what happened. This book seeks to provide a direction and a chart for future development and use of an energy technology from the preceding century that seems designed for the remainder of this century and the next.
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1

Modern Job for An Old Technology

The history of the United States is the history of optimism and progress; it has not been so clearly the history of organized and purposeful effort; it has been still less the history of Spartan dedication to great and difficult goals. We must believe that we can and will succeed; but we cannot succeed without discipline, self-denial, and vision. We have been efficiently pragmatic but we must remember that immediate utility is not enough. We should have a civilization favorable to the spirit which animated Galileo in the University of Padua, Newton in Cambridge, Helmholtz in Heidelberg and Berlin, and Niels Bohr in Copenhagen. The energy represented by coal seams and oil pools is limited... But as the quest of pure science is endless, so the results it may bring, the vistas it may open, are infinite.

Allan Nevins [1]

THE ENERGY EFFICIENCY EXPERT

Scientific and energy vistas opening today on cogeneration and district heating prove to be doors both to the past and
the future. The vision, discipline, and self-denial described by Professor Nevins as requirements for energy development, or for that matter, any other development qualifying as human progress, obviously apply to cogeneration and district heating.

The big advantage these methods have over other alternate energy sources is that the technology is already proven and well-established. Long research delays are not required. Several years, however, typically will be needed to lay pipe, retrofit existing equipment, and complete construction work in order to restore an abandoned district heating system or build a new one. Vision is essential to identify the future benefits of district heating systems if effort and funds are invested now. Discipline and self-denial will be welcome in any community trying to develop efficient energy systems. Progress is rare without them.

The following statement from a government report describes how this technology functions: “District heating is the use of one or more central heat sources to supply the low to moderate thermal needs of a community through a distribution system. The central heat source can be a heat-only boiler or a cogeneration (e.g., power plant producing both electric and thermal energy) facility. This type of system is becoming the dominant mode of operation in urban areas of the Scandinavian and Soviet Bloc countries.” [2]

The widespread reliance on district heating in much of Europe is a paramount reason U.S. advocates believe the technology should be rapidly introduced once more to U.S. cities, large and small. Delbert Anderson, Adviser on District Heating to the Minnesota House of Representatives, told the author, “My visit to European district heating systems convinces me that we can compare Europe and the U.S. and that district heating will save energy here the same as there.” Anderson was struck by the effective use of waste heat from cogeneration facilities. Anderson pointed out that during a seven year period in the 1970s, his state’s production doubled but its oil bill increased 20 times. “In Minnesota we feel an obligation to implement district heating as quickly as possible and attack this depen-
dence,” he said. “District heating is not a luxury, but rather a necessary move.”

The following descriptive definitions help illuminate what is involved:

**District Heating and Cooling:** A district heating and cooling system delivers hot water or steam from a central location to homes, offices, or commercial establishments. Supplementing thermal service and hot tap water, the system also supplies absorption air conditioning. With cooling service included, district heating is not simply a cold weather technology. In operation, hot water or steam travels through a network of underground pipes or through surface conduits to consumers. Among potential beneficiaries of district heating services are houses and apartments, businesses, university campuses, shopping centers, medical centers, industrial plants, airports, or any other comparable developments with heating and cooling needs.

**Cogeneration:** Cogeneration describes the combined production of electricity and heat energy. When fuel is burned to operate turbines for generation of electricity at a power plant, only about one-third of the heat energy is converted into electricity. A common practice has been to disperse the unused fuel energy as waste heat. Cogeneration puts this heat to work instead. The same principle can apply in reverse, as in the increasingly familiar case of using some steam to generate electricity in boiler plants whose chief purpose has been to produce steam for heat or other purposes. Various shopping centers and other large operations with extensive heat and electricity needs in a compact geographic area may find it beneficial in the 1980s and later to develop what are called “Total Energy Plants.” Such plants supply both steam or hot water for thermal applications and use a portion of the energy derived from fuel to generate electricity.

The Regency Square Shopping Center at Jacksonville, Florida exemplifies such an arrangement. This shopping center operates a Total Energy Plant to serve the 1.1 million square feet facility. Six Worthington internal combustion dual-fuel
Figure 1.1. This schematic shows the basic cogeneration process in which electricity is generated for power and hot water is produced for district heating.

engines are the main power source. Seven Caterpillar engines are also available to provide a total generating capacity of 14,050 kw. Exhaust heat produces steam for both heating and absorption air conditioning.

In 1981 Regency Square had arranged to hook up with the Jacksonville Electric Authority. Late at night the shopping center, with its power plant shut down, will draw power from the utility. During the day it will pay back power to the utility while serving its own needs from the Total Energy Plant. The resulting energy partnership is expected to approach a monthly power balance equally beneficial to the shopping center and the utility.

Comparable arrangements are likely in many other parts of the country. Total Energy Plants become economical and attractive as conventional fuel costs and electric rates go up. “The technical side is relatively easy. The hard part is working
Figure 1-2. With cogeneration, energy losses in the form of heat rejected to the environment are substantially lowered. Instead, this heat is delivered to district heating customers for heating and cooling applications. Overall energy efficiency is much improved.

out the details of an agreement with the utility," said a spokesman for the Florida shopping center which is demonstrating that cogeneration and district heating may be useful in a broad province and are not limited to areas of heavy urbanization with a cold climate.

$45-BILLION IN STAY HOME SAVINGS

Addressing a district heating meeting in 1980, Walter McCarthy, President of Detroit Edison Company, said, "Technical factors are least likely to impede district heating in this country. . . . Institutional and economic factors are the main obstacles. Many objections raised by utilities could be overcome through more favorable financing and more reasonable regulatory mea-
McCarthy realistically emphasized financial constraints working against rapid introduction of district heating in the United States. Economic considerations, he admitted, foster negative attitudes among utilities. The capital required for expansion of old or installation of new district heating systems in 1980 could be more profitably invested in less innovative power plant operations. McCarthy concurred, however, that district heating is a valuable method of energy conservation. He noted that cogeneration might extend energy efficiency from 35% to as much as 80% while simultaneously bringing about cleaner air and environmental improvements. "The significantly lower energy costs of coal and refuse produced steam are the keys to viability of district heating," McCarthy said.

The financial, institutional, and social problems voiced by McCarthy and others knowledgeable about the challenge of expediting district heating development in the United States are balanced for many observers by the pronounced need for this technology with minimum delay.

Another utility man, Peter J. McTague, President, Green Mountain Power Company, Burlington, Vermont, in a 1979 assessment of America's energy challenge, said the crisis "should result in use of thermal output from electric power plants for district heating." McTague claimed the crisis aspect with regard to energy lies in our inability to reach a consensus about the course we should take in planning our energy future; therefore, we have an energy crisis. The crisis is a deadly serious one. Fossil fuels propelled mankind in the course of 150 years to a tremendously high standard of living. . . . The essence of the current crisis is not the long-range problem or solution, but that we have to stay alive and productive in the meantime. To do this we must now develop our energy management skills. We must ensure the efficiency of every new energy system we build. We must maximize conservation of our currently available energy resources. As part
of this we must take another look at the European success with waste heat utilization. As you know, one effective method of doing this is through district heating systems. We will have to look more closely at district heating and cogeneration systems in this country, especially in situations where plants can be located to use the thermal discharge.

McTague made this useful statement in a keynote address to a meeting of district heating experts associated with the International District Heating Association (IDHA).

This influential association which is in close touch with district heating developments around the world is headquartered in Washington D.C. The Association was founded in 1909 with the avowed purpose of advancing the “art, science, standards and knowledge of district heating.” In the absence of an authoritative body of literature on district heating, quarterly issues of the Association’s journal, District Heating, are among the best continuing sources for regular update on the subject.

In a keynote address at a 1980 meeting of the IDHA, Gerald Leighton, Director, Community Systems Division, U.S. Department of Energy, declared that the nation’s energy challenge, like it or not, would require commitments “similar to those made in the Manhattan and Apollo projects.” [4]

“When the history of national energy policy is written,” said Leighton, “I am confident that one of the central themes will be how from the very beginning—that is, from the winter of 1973-74—conservation was correctly perceived as an especially appropriate response to the energy crisis. . . . Changing the ways in which an entire society thinks about—and uses—energy is an infinitely diffuse task. It involves millions of individual actors, great economic stakes, regional concerns, environmental issues . . . The President’s goal of cutting our oil import by one half by the end of the next decade—a saving of over four and a half million barrels of imported oil per day—cannot be met without a massive conservation effort. District heating, a central thermal energy source serving multiple independent users, has the potential for displacing enough petroleum by
itself, nearly to meet the President's goal. Of course, the full technical potential will not be met, and the time frame for implementation goes beyond this decade, but by the end of this century—twenty years hence—we predict that district heating could realistically displace 2,500,000 barrels a day of imported oil." [4]

U.S. Department of Energy predictions concerning district heating development have indicated that the technology could save U.S. energy consumers $14 to $28 billion dollars annually by the year 2000 based on oil prices of $30 per barrel. Thomas Stelson, representing the Department of Energy, told a district heating conference that at a projected cost of $50 per barrel for foreign oil in the year 2000, district heating has the potential in the United States to reduce fuel imports by $45 billion per year. [3]

Whether or not district heating systems are allowed to effect these savings depends of course on whether or not the systems are developed. Leighton and others emphasize that this is less a technical question than it is a social and political question. In his keynote address to the IDHA, Leighton said, "You notice that I have not said anything about technological

Figure 1-3. Estimated savings of scarce fuels for nine cities with cogeneration. A report from Argonne National Laboratory on Cogeneration District Heating and Cooling pilot programs shows in this diagram the potential savings of scarce fuels achievable through district heating based on cogeneration in nine cities combined. [3]
breakthroughs. I am convinced that the real challenge is institutional, economic, and psychological. Of course, we should develop more energy-efficient technologies and techniques. Above all, however, we need to surmount the kind of nontechnological barriers—attitudes, assumptions, behavior patterns—I have been discussing." [4]

Necessity, the mother of invention, may also be the architect of practical energy programs such as the implementation of district heating. "I think the necessity of being ready increases. Look to it," Abraham Lincoln wrote the Governor of Pennsylvania in 1861. The same instruction seems sternly appropriate for energy development 120 years later.

TAKING AN OLD PATH TO A NEW GOAL

District heating and cooling already allows millions around the world to derive maximum benefit from the energy they use. The same technology based on cogeneration should progress at an accelerating pace during the remainder of the century. The rationale for adoption of the technology is at once multifaceted and fundamental: It is a proven way with already established methodology for conserving scarce fuels, upgrading air quality, and improving the fuel efficiency of power plants.

While district heating systems are on the job in a large number of cities outside the United States, cheap and plentiful fossil fuels in the past kept American communities and institutions from adopting the conservation advantages inherent in the practice. This indifference and neglect are eroding fast and disappearing as the news spreads that a simple, readily available system successfully stretches both energy and energy dollars.

Development of district heating in the United States is gaining among private as well as public organizations. Urban revitalization and economic growth are two claims increasingly made as arguments for development. At the same time, the disadvantage of high cost cannot be ignored. Sufficient capital
for piping networks and building conversions does not routinely appear simply because energy logic and long-term reason would have it so. Many steam district heating systems in the United States have been uneconomical for several years, and these systems often are dropped by parent companies or allowed to deteriorate slowly until antiquated conditions make the systems obsolete. As utility experts suggest, the prospects for early development of new district heating systems are not great. However, if economic factors caused district heating to decline, changed economic factors may reverse the trend. The evidence grows that this is happening. The conviction that district heating systems pay for themselves and that they relieve pressure on tight energy supplies from the start of operations is perhaps more widely held today than at any other time during the past half century.

According to *Energy Future*, a Harvard Business School Report,

The advantages of cogeneration are substantial—about half as much fuel is used to produce electricity and steam as would be needed to produce the two separately. And it appears that the return on investment for many industrial firms (and for other establishments, such as hospitals and shopping centers) is quite good. Furthermore, cogeneration gives companies an important hedge against almost inevitable increases in energy prices and against brownouts and other interruptions of supplies, whether caused by oil producers, coal strikes, or bad weather. For utilities, cogeneration can reduce the need to build new nuclear or coal-fired power stations, at a time when marginal costs are higher than average costs—and at a time when the political obstacles to such new capacity are difficult to surmount in any event. As with so much else in conservation, cogeneration does not require a major technological breakthrough, but rather regaining a path that was abandoned.

Helge E. Nurmi, former President of the International District Heating Association, aptly stated what suffices as an introductory summary of the district heating situation in the 1980s:
“District heating systems can provide thermal energy from non-scarce fuels; can help restore the viability of cities; can provide relative low cost thermal energy; can provide reliable thermal energy; can provide resource recovery for refuse incinerators; can provide major means of energy conservation. The time for district heating rebirth is now in North America.” [6]

In other words, district heating is a promise with many attractive branches that may or may not be allowed to bear fruit. It is a technical success. A century of use in the United States and Europe supports the fact. But technical success is not the exclusive prerequisite for expensive programs requiring strong political backing and active public support.

Thus a vital part of the district heating challenge for the future manifestly involves effective marketing. Mayors, Legislators, Congressmen, Governors, Presidents, utility executives, energy committees, industry and institutional management, and citizens generally will have to sell district heating and themselves be sold on it. Subsequent chapters supply background information—historical, technical, financial—on district heating and cogeneration that should help decisionmakers begin with understanding about what is involved.

Fuel efficiency and the convenience of combining the production of electricity and heat in one operation explain why district heating and cogeneration expanded rapidly in Europe as fossil fuel shortages and prices applied steady pressure like subtle instruments of medieval torture. The same pressure has now found its way to North America, and “regaining a path that was abandoned” inevitably gathers new appeal as potentially the least costly and best illuminated energy path to travel beginning in the current decade and continuing ad infinitum.

Birdsill Holly no doubt would be impressed by the growth, maturity, and versatility of his 1877 brainchild.

REFERENCES


District Heating
Historical Perspectives

It is hard to believe in this last quarter of the Nineteenth Century that for even one day New York could be so completely isolated from the rest of the world as if Manhattan Island was in the middle of the South Sea . . .


The steam supply company supplied steam without interruption to all its customers.

*Scientific American*, March 24, 1888

STEAM AND THE BLIZZARD

The contemporary reliability and steady performance of district heating systems can be projected backward more than 90 years. Consider, for example, the famous “Blizzard of ’88.”

A storm to remember bludgeoned New York City and smashed other areas along the Atlantic seacoast beginning March 11, 1888. The blizzard continued through March 12th, growing in fury. The *New York Herald* on March 13th reported, “A great white hurricane roared all day through New York yesterday and turned the comfortable city into a wild and bewildering waste of snow and ice. . . . When day broke the
Figure 2-1. Park Avenue after the Blizzard of 1888. When the storm battered the city, little moved on the surface or through the city streets. Underground, however, district heating steam surged steadily through the pipes carrying heat to those lucky or wise enough to be connected. (Courtesy of The New-York Historical Society, New York City.)
city presented an amazing appearance. . . . At every turn could be seen these deserted vehicles.”

The “Big Apple” was literally brought to a standstill. The city was paralyzed with horse-drawn streetcars unable to leave the barn and with trains immobile. So much damage was done throughout the city to overhead telephone and telegraph wires, a plan to put all such wires underground moved ahead quickly after the city recovered.

“A storm like this is to be looked upon in the same light as an earthquake,” declared Scientific American in its March 24, 1888 issue.

Delivering food and fuel were especially serious problems in the stalled metropolis. Surface deliveries were almost impossible. “Coal and all objects that had to be transported on the surface were only with great delay and at the cost of great efforts delivered to those requiring them,” observed Scientific American. Thousands of New Yorkers simply had to do without until Nature’s temporary uproar subsided. Snow drifted to second story windows as winds up to 84 miles per hour whipped the frozen flakes mercilessly about. The magazine that in 1888 called itself “a weekly journal of practical information, art, science, mechanics, chemistry, and manufactures,” said the area of the storm stretched from Boston to Washington with New York City at the center. The storm was popularly called “the blizzard,” said Scientific American, and explained that “it approached pretty closely to the Western definition of that type of storm, ‘three feet of snow and all of it in the air.’”

The magazine reported only one city service entirely unaffected by the storm. New York’s district heating operation continued delivering steam to customers without letup, mishaps, or delays.

“The steam supply company supplied steam without interruption to all its customers,” commented the magazine.
Figure 2-2. *Digging out after the blizzard.* Coal and wood couldn’t be delivered in Manhattan March 11-12, 1888, but one heating medium was never slowed nor stopped: steam district heating. (Courtesy of The New-York Historical Society, New York City.)
The undisturbed effectiveness of the district heating operation despite surface tumult and turmoil led *Scientific American* to suggest, “In this and other features of the situation, a powerful argument was found for the introduction of underground transportation.” New York subway riders are probably not aware that their fast and efficient if sardine-crowded journeys underground are due in part to the trouble-free efficiency of district heating steam service throughout the powerful Blizzard of '88.

The strength and sovereignty of nature were vigorously displayed during the blizzard. The scope and intensity of the display also serve to stress the remarkable dependability of the city’s district heating system, which was less than ten years old but no less trustworthy then than the same service is today over 90 years later.

The roots of district heating development can be traced far back in history. John F. Collins, Secretary-Treasurer of the International District Heating Association, 1939–1964, extensively researched district heating’s ancestry and published his findings in the Association’s journal. [1] What Collins learned provides a curious and fascinating background for the energy technology that might be superficially seen as simple and ordinary. Perhaps it could be accurately stated that district heating is simple enough not to break down because of sensitive or excessive complexity, and complex enough to perform a versatile job with reassuring consistency.

**TAKING A HOT BATH IN ANCIENT ROME**

As with much else in western civilization, we can look to the practical Romans for early examples of primitive but effective district heating activities. The Romans took special care to organize the important details of their lives including their baths. Roman baths were heated by passing heat from fires through tile ducts. Bath water was said to have been heated by passing it through heated brass pipes.

Descriptions of Roman cities at the height of the Empire
interestingly echo descriptions of modern European cities with clean air and streets surrounding neat apartment complexes, all partially attributable to district heating systems. Aelius Aristeides in the 2nd century A.D. wrote, “Everywhere are gymnasia, fountains, gateways, temples, factories, schools, and it could be said in technical phrase that the world which from the beginning has been labouring in illness has now been put in the way of health. . . . Cities are radiant in their splendour and their grace, and the whole earth is as trim as a garden.” [2]

Roman water systems in their carefully planned towns were predecessors of later district heating piping systems. Water was conveyed through underground channels or by means of aqueducts to storage tanks. It was carried into houses through lead pipes (later identified as a potential source of poisoning and hypothesized by some as one reason for the demoralization and ultimate decline of the Roman Empire!). Fourteen aqueducts with a total length of 265 miles served the city of Rome. “Low-pressure pipes were used: high pressure implies cast-iron pipes which the Romans could not make. . . . The maintenance of aqueducts was a public service carried out by state or municipal servants.” [3]

Roman houses contained many early ancestors of conveniences now taken for granted in modern homes. “Rich houses might enjoy a primitive type of central heating,” wrote R. W. Moore, “in that certain rooms might be heated from below by a furnace whose heat circulated under a floor raised on little pillars of tiling, and came up through concealed shafts around the walls.” [4]

The pragmatic Romans with their penchant for orderly, organized living laid the foundations for much that came later, including district heating. The history of modern civilization could be persuasively written in terms of mankind’s growing sophistication at solving the constant problem of home heating.

BENEFACTORS OF MANKIND

Benjamin Franklin, America’s first energy expert, specializing in home heating, invented his Pennsylvanian Fireplace to solve
the common dilemma with conventional stoves in the 18th century of “being scorched before, and, as it were, froze behind.” Franklin used some of the circulation principles later refined in home heating and subsequently in district heating developments. Franklin called those who help people use fuel efficiently “benefactors of mankind,” and he applied considerable portions of his long life to research and speculations that qualified him for the title. [5]

Paralleling European and American efforts to use fuel efficiently, people in other parts of the world confronted the same problem. Franklin’s 18th century researches impressed him particularly with the skills of the Chinese in the management of fire. He advised Westerners to learn from the experience of the Orient. “The Chinese, whose country being greatly populous and fully cultivated, has little room left for the growth of wood; and, having not much other fuel that is good, have been forced upon many inventions during a course of ages, for making a little fire go as far as possible.” [6]

Among early heating systems that stand as precursors of modern district heating systems was the 1716 hot water system designed by Sir Martin Trienwald in Sweden to heat his greenhouse. The water was distributed through copper pipes, and wood was used as fuel. Sir Hugh Plat, an English lawyer and horticulturist, in 1742 used pipes to distribute live steam into a room for heating purposes. This in effect turned the room into a Turkish bath. It was warm but uncomfortably damp. Back to the drawing board. More effectively, Plat piped steam from a heat source into his greenhouse.

Sir William Cook in 1745 used pipe coils to steam heat his Manchester, England home. John Collins noted, “This could be said to be the first attempt to warm a group of buildings from a single source of heat.” [1]

At Philadelphia later in the 1740s, Benjamin Franklin used an iron stove-furnace underground to heat a row of houses in a limited but authentic application of district heating principles. A 10-inch iron pipe beneath the floors served as the flue. Brick walls and a tiled top enclosed this box-pipe to prevent fires.
Throughout the 18th century, in many places men were applying their hands, skills, and wits to improve heating services for themselves and their neighbors. James Watt in 1774 heated his upstairs workroom with heat from a basement boiler. Hoyle of Halifax obtained a patent on a 1791 system using pipes filled with steam to heat a building. An inventor named Green in 1793 passed a 3-inch steam line through a 9-inch air duct around the edge of the floor. Jacob Perkins and the Marquis de Chambonne used hot water as their heating medium for an 1816 heating system they introduced in England. In the United States during the 1830s, Nason and Walworth installed hot-water heating systems and manufactured cast-iron fittings. In the 1850s Crane manufactured valves and fittings as the production of heating equipment became an important enterprise. In 1865, according to Collins, J. P. Marsh started steam, vacuum, and pressure gauge production. Samuel Gold’s 1859 radiator offered improvements over pipe coils for heating. Gold also patented a sectional cast-iron boiler. In 1860 cast-iron radiation had reached the stage of general marketing and use.

While one group of inventors was struggling to use steam more effectively for heating purposes, other inventors were putting it to work in what became one of the great revolutions of mankind. A British mechanic named Thomas Newcomen in 1712 took what has been called “one of the longest steps in history” when he radically improved a primitive steam water lifting device invented by Thomas Savery. Newcomen directed steam against a piston forcing it up, and he used a cold water spray to condense the steam which created a vacuum drawing the piston down. This reciprocating action delivered pumping energy that was soon used effectively to pump water from mines. His vital work earned Newcomen credit as inventor of the atmospheric steam engine.

Historian Allan Nevins acclaimed this 1712 feat as “an event beside which Marlborough’s victories pale into insignificance. Mankind could turn its face from the muscle energy of horses, elephants, slaves, and servants, from the windmills of Don Quixote’s Spain and the water mills of a thousand streams.” [7]
This was true, but more work was needed before the steam engine could come fully into its own. Later in the 18th century James Smeaton built an improved steam engine to replace windmills, but the significant breakthrough came from a Glasgow instrument-maker and genius named James Watt. Watt put the ingenuity he had used to heat his workroom to the problem of making a Newcomen engine more efficient. This came about when the University of Glasgow hired Watt to repair a Newcomen. Until Watt studied the problem, the Newcomen engine wasted most of the energy produced from fuel. Watt identified the main source of energy waste as the process of alternately heating the cylinder with steam and then rapidly cooling it with water to condense the steam. The inventor installed a separate condenser so the cylinder could stay hot, and he redesigned the machinery for two power strokes instead of one with each revolution. Then a revolving shaft, representing the finesse of genius, with gear arrangements made the engine a versatile tool for countless other work assignments as well as mine pumping.

BIRDSILL HOLLY PIPES STEAM

“The age of steam had arrived,” wrote Nevins. “The age in which a Boulton & Watt engine was soon giving energy to factories, and driving Fulton’s Clermont on its historic voyage up the Hudson.” Effective management of steam for work led as well to its management and use for district heating. Birdsell Holly, wrote Collins, “deserves all credit as the first to put district heating on a successful commercial basis.”

Birdsell Holly, born at Auburn, New York in 1820, lived at 31 Chestnut Street in Lockport, New York when he conducted his district heating experiments during the 1870s. Holly was an inventor and hydraulic engineer with a rotary water pump and Sybill steam fire engine among his 150 or more inventions. While working at his inventions, Holly ran a factory manufac-
turing various products including sinks, cistern pumps, and sewing machines.

One of Holly’s successful experiments with a basic district heating connection involved pumping steam through pipes under pressure. Holly developed the scheme of sending steam through pipes to heat buildings. He constructed a boiler in the basement of his house on Chestnut Street.

“The grate was a sheet of steel with holes drilled in it,” wrote John Collins in his detailed report on this historical event. “Pipe coils were used for radiation. He ran the steam line to a ‘distributor’ in the attic of his home, then down to coils in the various rooms and back to the basement. There, a loop served as a trap and condensate was returned to the boiler which operated at 10 psi pressure.” [1]

With this “central heating plant” successfully rigged out, Holly was ready to conquer new worlds—send the steam underground through pipes to heat other houses in the neighborhood. Using 1-inch pipe buried in lawns, Holly delivered steam heat. Then he tried 1.5-inch pipe wrapped in asbestos, felt, and manila paper for insulation. This 490-foot pipe was buried approximately 3-feet deep in a sawdust-filled wooden box.

When his experiments and their variations demonstrated the practicality of his steam district heating system, the inventor organized the Holly Steam Combination Company with initial capital of $25,000. At 1981 prices this amount would finance only a few dozen feet of district heating pipe in most American cities.

Holly used his capital to acquire a secondhand boiler in Buffalo, New York and to bring it to Lockport by way of the Erie Canal. The 7-foot by 10-foot boiler was housed in a boiler house built with a 30-inch square stack, 30-foot high. Then 2350 feet of 2-inch and 4-inch iron pipes were laid. The pipes were enclosed in a bored-out wooden water line which supplied necessary insulation. Fourteen customers were connected to Holly’s central system by means of these pipes, and with his boiler operating at 30 psi, Birdstill Holly started district heating steam
service during October 1877. Few historians have taken note of this event, but it was an important advance for mankind.

Holly’s natural inventiveness was not finished. To his successful system, he added “a steam trap, an expansion joint (the variator), a tin atmosphere radiator, an iron pipe atmospheric radiator, a pressure regulator, and a condensate meter.” [1]

Boiler problems developed the first winter because of foreign substances invading the system. A screen took care of this. “A new water tube boiler was also added,” wrote Collins. “By 1879 there was in service 14,000 feet of line. Among Mr. Holly’s unusual inventions was a steam stove, designed to enable school teachers in the local school to heat their food.”

The steam stove is an indication that Birdsill Holly was already thinking about the cogeneration possibilities inherent in district heating—the logic of using the steam for multiple purposes.

By 1880 Holly’s district heating efforts were definitely leading toward cogeneration versatility. An 8-inch line under 80 psi pressure was extended to a number of factories for delivery of process steam. Exhaust steam from the factories was used for heating applications. This century-old energy partnership is precisely what modern cities now recognize as their “newest energy option” when they adopt cogeneration and district heating as the best use they can make of available energy and the surest means of supplying their long-term needs.

The industry Holly launched soon left him behind when rapid growth occurred in many sections of 19th century America. The inventor, according to Collins, died a comparatively poor man though he had laid the groundwork—literally—for steam and power companies to earn millions and for mankind to save trillions through energy efficiency. If he did not benefit to the extent he deserved financially, Holly at least had the inventor’s special and privileged satisfaction of knowing that he was first. Other inventors, engineers, and scientists will appreciate that this was not trivial payment for his innovative work.

The American District Steam Company was formed in 1881
to supply district heating equipment for a quickly booming industry. The new and efficient technology spread outward from Lockport to other cities and states as the word got around that a man there was doing something peculiar but profitable with steam.

Companies selling steam district heating service were soon doing business in Pennsylvania, Connecticut, Massachusetts, Iowa, and as far west as Denver, Colorado.

District heating technology had an amazingly brief infancy. In a few years at the end of the 1870s and the start of the 1880s, it leaped from nonexistence to maturity. Considering the long delays for energy developments during the last quarter of the 20th century, those involved who look back nostalgically to district heating developments in the 1880s may find a special meaning for the expression, "the good old days." Those were the days when large-scale energy projects moved ahead rapidly, unhampered by the massive social, financial, and regulatory barriers that slow such projects in the 1980s to a snail's pace, an especially sluggish snail.

DISCOVERING COGENERATION

The cogeneration opportunity did not remain unnoticed when Holly's technology made steam sales profitable. A large number of small electric companies developed to supply the country's eager appetite for electrical service following Edison's breakthrough work at the end of the 1870s. These plants, typically sited in concentrated urban areas, used electric generators operated by reciprocating steam engines. Unused or waste steam commonly was exhausted to the atmosphere. But Birdsill Holly had proved that steam itself was a marketable commodity, and many small utilities began doing just that—selling surplus steam for district heating applications.

By 1909 an estimated 150 companies sold thermal energy in this or related manner across the United States. Electric utilities entered the district heating business as a logical means of in-
creasing their electric loads and to meet customer requirements. [8]

Energy users wanted both electricity and heat. If both could be delivered conveniently from the same source at a fair price, there were benefits for all concerned and energy waste was reduced to a minimum. In substance this is the situation with regard to district heating in the 1980s as history in a sense repeats itself. Holly’s technology after long decline in the United States once more is becoming economically viable thanks to energy conservation factors that might make district heating an imperative option whatever the cost.

What utilities could do, some buildings and industries decided they too could do. They could connect their boilers to electric generators through reciprocating engines and manufacture their own electricity, using energy that otherwise would largely be lost.

Cogeneration systems of this type were abundant in the United States during the first decades of the electricity revolution. Utilities were often expected to provide thermal energy service as well as electric service. Now the cogeneration lessons first mastered during that late 19th century and early 20th century period are relevant again.

Birdsill Holly lived until 1894. He lived to see his original energy idea become the seed from which district heating systems were developed to warm the homes of American city dwellers. He did not live to witness the decline in district heating use that came in the 20th century as a result of changing American lifestyles, energy needs, and utility performance. Consideration of the reasons for the decline in the use of district heating in the United States will follow a look at the beginnings of what is today the world’s largest district heating system.

REFERENCES

COGENERATION AND DISTRICT HEATING

3. Ibid., pp. 132–133.
Developing the World’s Largest District Heating System

While I was digging the trenches and putting in the tubes in several miles of street in the First District, The New York Steam Company was also digging trenches and putting in steam heating pipes. Mr. C. E. Emery, then chief engineer, and I would meet quite frequently at all hours of the night, I looking after my tubes and he after his pipes. ... I thought he had a harder proposition than I had, and he thought that mine was harder than his.

Thomas Alva Edison [1]

PLANTING STEAM PIPES AT NIGHT

The New York City steam district heating system that stood up to the rigors of the Blizzard of '88 was only in the planning stage less than a decade before when financier Wallace C. Andrews sent engineer Charles Edward Emery in 1879 to Lockport, New York with the assignment of preparing a firsthand report on Birdsill Holly’s invention. Was it “Holly’s folly” or was it a practical answer to the mammoth task of heating rapidly growing New York City?
Emery’s report obviously was favorable, because Andrews proceeded to form the Steam Heating and Power Company of New York, with Emery as the chief engineer, to give the city a functioning steam district heating operation. Following the acquisition of a failed competitor, the company’s name became The New York Steam Company which survived to modern times as a subsidiary of New York’s Consolidated Edison Company.

As the New York district heating system developed and lines were constructed, by coincidence Edison electric power lines were being placed at the same time. The possibility that an electric power company and a steam company could unite to serve customers through cogeneration was not explored at that point, though this move was not far distant. Eventually Consolidated Edison would supply electricity to millions while running the world’s largest steam district heating service for more than 2000 apartment buildings and offices in Manhattan.

Emery’s 1880s pipe-laying efforts under the sidewalks of New York clearly were conscientious and effective. The Emery pipes delivered steam without pause through the Blizzard of ’88, and some of them were still on the job well over 60 years later. [1]

Thomas Edison became a friend of Charles Emery and monitored the progress of his pipe-laying in the vicinity of Edison’s electric lines. Edison and Emery objectively discussed the work of the competitive steam company that began laying pipes at night in Maiden Lane. All of them did their pipe work mainly at night to avoid being trampled by people and horses in daylight traffic.

“One thing we both agreed on, and that was the other steam heating engineer hadn’t any chances at all, and that his company would surely fail,” wrote Edison. “If he, Emery, was right the other fellow was wrong. Emery used mineral wool to surround his pipes, which was of a fibrous nature and was stuffed in boxes to prevent loss of heat and pressure, whereas his competitor was laying his pipes in square boxes filled with lampblack.”

Edison and Emery were accurate in their assessments. The
Figure 3-1. *Steaming up the city.* At 700 First Avenue near the East River in Manhattan, the Con Edison Waterside Generating Station produces some of the steam needed by the world's largest district heating operation. Since 1882 district heating has been continuous in Manhattan.
A TRADITION OF STEAM IN MANHATTAN

On March 3, 1882, the initial customer, the United Bank Building in Downtown Manhattan at Wall and Broad Streets, received steam through pipes from The New York Steam Company. The building used the steam for power, pumping, and elevator service. It left the historic privilege of first using New York district heating for actual heating to others. [2]

In succeeding decades, countless millions of New Yorkers relied on the city’s intricate steam district heating network for warmth and many other applications. Just as the United Bank Building from the first day had more uses for the steam than simply heat, so the city’s citizens through the years have applied the steam to a multitude of jobs including cooking, laundry, refrigeration, and industrial processes.

The versatility of a metropolitan district heating operation has been dramatically illustrated in New York around-the-
clock for years. Visitors in Manhattan may sometimes be startled to see steam rising through street and sidewalk openings, and they may think the threatening underworld is coming to the surface. But this is only Con Edison venting a little free steam from its miles of underground district heating pipes, some put in place a hundred years ago by Charles Emery and his fellow night workers.

City dwellers take district heating services for granted, seldom thinking about the underground steam pipes and what has been done with that steam longer than practically all New Yorkers have lived. The steam presses suits and in the old days it blocked hats on a large scale during the years when most men wore hats. Barber’s towels, Turkish baths, dish washers, meals in gourmet restaurants or in “greasy spoons”—all historically relied on district heating steam.

New York buildings are steam-cleaned. A jet of steam used to thrill or scare an audience in a Broadway theater may come straight from the district heating bowels of Manhattan.

The 19th century demonstration of district heating’s success in a large city by Andrews, Emery, and their coworkers, was a highly important extension of Birdsill Holly’s development. The New York experiment proved that district heating worked brilliantly in a metropolitan setting. It notified energy managers of the 19th century and the 20th that district heating was available and would work in their cities too when they needed it or got around to it.

**AVOIDING COLD WITHOUT COAL**

District heating led slowly to vital changes in New York and other cities that followed New York’s lead. “For the first time in the recorded history of the Temperate Zone, architects began erecting buildings without chimneys,” wrote Harry Granick. “They employed the valuable boiler space for vaults and stores and workshops and dining rooms. They ripped the boilers out of old structures and put the space to profitable use.
COGENERATION AND DISTRICT HEATING

It was cheaper and cleaner to buy steam than to make it.” [1] Granick grew up in New York during the early part of the century before steam service had become widespread in the city. At that time most apartment houses constructed before 1914 used coal stoves in every kitchen. Many of these buildings turned to steam heating after World War I, but in Granick’s youth a common chore was carrying coal ashes to the street and bringing back buckets of coal. “The waste was terrific, the smoke dense and full of soot, and the sidewalks dirty with uncollected ashes often exposed to the wind,” wrote Granick. As district heating gradually displaced these individual sources of urban pollution, the city gradually escaped its pall of coal smoke and became cleaner than it had been since the early days of the Dutch settlers.

In the 18th century Benjamin Franklin wrote to his wife from London where burning coal in individual home stoves was the common practice. “The whole town is one great smoaky house, and every street a chimney, the air full of floating sea coal soot,” protested the traveller. [3]

District heating in New York allowed coal still to be burned, but this was accomplished by the power company in giant plants that could have their emissions controlled and scattered more efficiently and less harmfully than would ever be possible from a city crowded with thousands of chimneys. Long before modern emission standards and pollution regulations imposed strict requirements on power companies, district heating was an unsung and often unrecognized boon to citizens who prefer a blue sky to a brown haze over their heads.

U.S. oil and natural gas supplies are dwindling, but the nation has vast reserves of coal. The time may arrive, as some experts believe, when electric production in the U.S. will have to be predominantly from coal. Coal may also have to provide the bulk of the country’s thermal energy as well. To avoid ecological and environmental disaster if this change occurs, use of the coal in district heating systems will be essential.

New York City graphically showed the penalties of coal use by individual tenants and the improvements resulting from a
shift to district heating. Writing in the 1940s, Harry Granick acknowledged the benefits New York derived from generating steam in 8-story boilers which was used both to generate electricity and then sent out as "white energy that charges hotly under Manhattan streets into the skyscrapers and into most of the hotels, theaters, apartment houses, factories, department stores and wealthier homes from the Battery to 92nd Street." [1]

The author lived 17 years in Manhattan apartments receiving steam from the city's district heating system. This service was one of the most reliable provided during years when other city services suffered from growing financial malnutrition and chronic deterioration. It became easy to understand why steam kept moving during the Blizzard of '88 when nothing else moved.

Steam distributing mains in New York were laid 4 to 15 feet deep and interconnected beneath the streets so any generating station can deliver steam throughout the system. Various improvements have been made in the system through the years, but the system is essentially little altered by time. Valves permit operators to send greater steam loads in any direction desired. Pipe sections have copper joints which allow enough expansion to prevent buckling. The streets and sidewalks of New York have enough deliberate holes in them for the city to qualify as a mammoth prairie dog village. These are manholes allowing Con Ed workmen access to the underground city where the steam pipes go about the business they have carried on continuously for nearly a century.

From the distributing mains, steam enters customer buildings through thousands of service pipes. The process is elaborate and the underground pipes form what would seem a maze impossible to unravel for the uninitiated. But the fundamental nature of the system is still largely what it was in 1877 when Birdsill Holly sent steam through pipes to his first 14 customers.

In a salute to the improvements wrought by steam district heating, Granick called New York with its reliance on underground steam pipes, a "city without chimneys." He wrote prophetically about what district heating could mean elsewhere:
“Some day, no doubt, all civilized communities will be centrally heated whether by steam, electricity, or atomic energy. In that day, you will find if difficult to explain to your children or grandchildren why it was not possible to do so sooner; why precious coal had to be wasted in tiny individual furnaces . . . why you had to suffer the insanitary nuisance of thousands of small, inefficient chimneys each polluting the air.”

DISTRICT HEATING TODAY IN NEW YORK CITY

Nearly 35 years after Granick wrote, his prediction about district heating has not come true; but there are indications that changing energy facts-of-life may still make him an accurate prophet. Coal is no longer a serious urban nuisance, but when shortages of other hydrocarbon fuels bring back the coal trucks and ash cans, New York City’s 1879 solution will continue to be valid in 1989 or later for all cities with barber’s towels to heat, dishes to wash, food to cook, laundry to do, and thousands of rooms to warm and cool.

New York presumably will continue to accomplish these tasks as it has since the days of horse-drawn vehicles on Fifth Avenue. In 1978 Consolidated Edison sold 32 billion pounds of steam to 2,300 different customers. [4] Figures reported for 1975 were larger: 35 billion pounds of steam sold to 2,519 customers over 109 miles of distribution lines.

Some decrease in sales has been characteristic of many U.S. district heating operations in recent years, but the energy factors of the 1980s and 1990s will not be the same as those that brought about the decline in sales. Each district heating situation in the U.S. tends to be unique, and New York City certainly is not an exception; but many operations during the remainder of this century, including the New York operation, should share improved prospects simply because district heating and cogeneration together are more efficient and thus potentially more economical than power generation alone.

New district heating customers in U.S. cities probably will
be easier to find as a result of oil/gas shortages and climbing costs.

Taking 1975 as a representative recent year, district heating in Manhattan as supplied by Consolidated Edison stretches from the southern tip of the island (where you catch the Staten Island Ferry or see the Statue of Liberty standing in the harbor) north or "Uptown" to 96th Street on the West Side and 89th Street on the East Side. District heating steam lines parallel Central Park on the West Side running near Central Park West.

Approximately 70% of the steam comes from cogeneration plants, 30% from steam-only stations. The steam system peaks in the winter, with a 1975 peak sendout of 12,325 million pounds/hour. In the 1970s, the use of steam for summer air conditioning tended to level seasonal load variations. The load factor in 1975 was 38.8%.

Steam is generated at 200–400 psig and delivered at 125 psig. Steam condensation is not returned as in some European operations. Distribution losses amount to 15–20% of steam sendout. Primary fuels in 1975 were #2 and #6 oil. The following table summarizes significant data applicable to 1975:

Table 3-1. Consolidated Edison Steam Data (1975)

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<tr>
<th>Description</th>
<th>Value</th>
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</thead>
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<tr>
<td>Maximum Hour Load</td>
<td>12,325 MLB</td>
</tr>
<tr>
<td>Load Factor</td>
<td>38.8 percent</td>
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<tr>
<td>System Capacity</td>
<td>15,555 MLB</td>
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<tr>
<td>Steam Sales</td>
<td>34,587,618 MLB</td>
</tr>
<tr>
<td>Total length of mains and services</td>
<td>108.6 miles</td>
</tr>
<tr>
<td>Unit Production Costs</td>
<td>352.05 ¢/MLB</td>
</tr>
<tr>
<td>Number of Customers</td>
<td>2,519</td>
</tr>
<tr>
<td>10 year rate of steam sales growth</td>
<td>2.723 percent</td>
</tr>
</tbody>
</table>

With some steam distribution mains still in service since Charles Emery’s night crew put them in place, Con Ed has sought ways to improve the system and reduce losses that occur
Figure 3-2. The Con Edison steam system in Manhattan. Steam lines cross and crisscross Downtown and Midtown Manhattan, going south to the Battery and north paralleling Central Park. The city’s world-famous financial and theatre districts are included.

during distribution. Costly improvement plans have never been simple to implement, however, because the return on steam
investment capital typically has fallen below the return on electricity and natural gas.

A report in the 1970s concerning national district heating activities summarized the New York district heating operation with this statement:

The problems of New York City are, to a certain degree, reflected in the operation of a district heating system within city limits. Subsurface street congestion, high local taxes, well-organized opposition causing construction delays and unreasonable union demands and work restrictions place a heavy burden on the economics of Con Ed steam system operation. The system would be interesting for our purposes primarily because of its size and operating arrangements.

It is not expected, however, that a case study of the Con Ed system would produce a strong economic argument in favor of the district heating systems.

The likelihood is strong that Con Ed will be in the district heating steam business a long time. A service that lasts a hundred years becomes both a tradition and a habit, equally hard and unpleasant to break. If the Blizzard of '88 chooses to make a nostalgic return in 1988, the steam tradition in Manhattan should be prepared to carry on, and there is reasonable certainty that it will. Steam will pass undisturbed through the almost 109 miles of insulated pipes on its way to skyscrapers and apartment buildings. The city has changed many ways during the past century, but in that energy assurance, it has not changed and hopefully will not change. Credit now, the same as then, is still due Birdsill Holly's invention and the 19th century New Yorkers with vision to recognize the promise of district heating and the tenacity to develop a remarkably durable system for the city.

New York's example of diligence and preservation, despite problems, should help other cities resist the temptation to dismiss district heating as a white elephant. An energy system that keeps people warm, fed, and clean for a century can't be all bad. This fact should prove district heating does its job
when given a chance, and it may help encourage revival of this practical technology in American cities during the final years of the 20th century after a long period of American energy gluttony and slow district heating growth through an era when most Americans found it painful to be practical and farsighted.

REFERENCES

Rise and Fall of U.S. District Heating

It was at Rome, on the 15th of October, 1764, as I sat musing amidst the ruins of the Capitol, while the barefooted friars were singing vespers in the Temple of Jupiter, that the idea of writing the decline and fall of the city first started to my mind.

Edward Gibbon [1]

ELECTRIFYING YEARS

The great empire of Rome is believed to have fallen because of internal strife, decadence, low morale, indolence, and corruption. “It has been calculated by the ablest politicians that no State, without being soon exhausted, can maintain above the hundredth part of its members in arms and idleness,” wrote Gibbon, classic chronicler of the empire’s decline and fall.

Romantic vicissitudes, self-indulgence, and corruption cannot be offered as excuses for the decline of district heating in America. The technology worked splendidly. Steam companies did a land office business. Customers were satisfied. Then came technological and lifestyle changes, and gradually district heating as it began in America simply wasn’t needed anymore. However, unlike the Roman Empire, district heating rose rap-
idly to the ascendency, then declined, and now shows marked signs of rising once again.

After several successful decades, district heating gradually became less important in the United States and opportunities for district heating energy conservation were increasingly ignored. This occurred largely because of technical progress in the production and transmission of electricity. Electric turbines supplanted reciprocating engines. This eliminated the inexpensive steam associated with early district heating steam systems in many parts of the United States. “There was no longer any exhaust steam available for heating, and condensing water did not have a high enough temperature for heating,” wrote John Collins. “Larger electric plants became the rule, replacing groups of smaller ones and these plants were moved away from congested areas as electric transmission became possible over greater distances. As generation of electricity became less expensive in larger plants, the smaller ones in towns from which steam was obtained became obsolescent. Steam which had been regarded as an inexpensive byproduct and sold by the electric companies at a very low price, had to bring a return or at least balance expenses.” [2]

When steam rates could not be increased sufficiently to show a comfortable profit, various utilities found it expedient to close down their district heating operations. Economic considerations prevailed as they usually do in most matters from shoes, ships, and sealing wax to energy. The phenomenon of America’s demand for electricity is one underlying explanation. The district heating operations associated with small utilities generally located within their own service areas became technically impossible when the small utilities were replaced by one giant utility that migrated to the suburbs.

Economies of scale coupled with technological improvements in transmission resulted in the location of power plants at considerably greater distances from the cities they served. The small power plants ideally located to supply neighborhood district heating service were closed down and their sites gradually swallowed up by apartment complexes, shopping districts, office buildings, and parking lots.
With the disappearance of the small generating plants, the opportunity for simple and inexpensive district heating operations also disappeared. The greater distance between power plants and potential customers for district heating service became too great for convenient or practical transmission of steam. Steam optimally serves customers only within 2 to 3 miles of the plant.

Thermal systems that might have continued to be effective in large cities as complementary services with electricity were increasingly challenged on economic grounds. Did they pay for themselves? Did they show a profit? Answers to these questions became critical in many locations, and the answers not unusually during an era of low energy prices were often unfavorable for district heating.

**DRIVING AWAY FROM DISTRICT HEATING**

Following the rapid early growth at the end of the 19th century and the first two decades of the 20th century, district heating as a cogeneration dividend of power plant operations became more a technological possibility than a reality. In the 1920s and 1930s, district heating systems that were not financially self-sustaining frequently ceased to function despite their continued ability to conserve energy. Before the 1970s, conserving energy was generally seen as an unamerican activity. Petroleum and natural gas were plentiful, and it was incumbent on good citizens to use them liberally. Most Americans in the 1940s, 1950s, and 1960s were very good citizens indeed.

The triumph of the American automobile was another conspicuous factor. Sustained and transported by the family flivver, Americans in their millions took flight to the suburbs. The use of oil and gas multiplied exponentially, Americans lived farther and farther from central cities, and district heating inevitably received a critical blow. Many systems could not survive, because their logical customers had gone away.

The availability of cheap and plentiful fuel fostered, stimulated, and long maintained the 20th century exodus of
Americans from decaying cities to freshly bulldozed outlying neighborhoods. These spread-out residences were economically unsuited for district heating, especially with the pump prices on gasoline, the barrel prices on heating oil, and the near giveaway prices for natural gas. With fossil fuels considered inexhaustible and with costs even Dust Bowl migrants could somehow afford on Highway 66 in the Depression 1930s, the conservation and efficiency benefits of district heating were unnecessary and therefore unrecognized.

The automobile symbolizes this 20th century American trend, and the automobile may also symbolize the turning of the circle and the establishment of a new trend that takes Americans back to energy conditions that give the declined district heating industry another chance to expand.

Essayist E. B. White hailed the family flivver and the era it created and he also said farewell when he wrote, “The days were golden, the nights were dim and strange. I still recall with trembling those loud, nocturnal crises when you drew up to a signpost and raced the engine so the lights would be bright enough to read destinations by. I have never been really planetary since. I suppose it’s time to say goodbye. Farewell, my lovely!” [3]

As the expense of driving long distances to and from work mounts, this statement is being heard increasingly: “Maybe we should move closer to the city.” Those words, rarely heard in America during the last fifty years, carry a promising message for district heating. Piping heat from power plants or industries to U.S. homes, apartments, offices, and businesses makes sense again when the bottom of the petroleum barrel if not seen is at least anticipated.

Economic concerns made district heating a natural choice in Europe following World War II. U.S. energy economics in the 1980s are accomplishing the identical feat. Birdstill Holly’s 19th century methodology once more can assist Americans in staying warm without turning the thermostat back to zero, can help them handle skyrocketing energy prices, can reduce consumption of scarce fuels, and can measurably clean the air with
corresponding benefits for human health. It can. The question asked and unanswered is whether it will.

New district heating developments in the U.S. fortunately can call on the experience of an industry that never actually disappeared in this country and that has flourished technically in other countries. Many district heating operations passed into history during the middle years of this century, but U.S. district heating survived thanks to apartment dwellers, industrial, institutional, and commercial customers in large American cities. Some utilities built heat-only systems without the energy efficiency aspects of cogeneration. These systems were designed to fill urban heating needs. The American district heating industry provides a sturdy foundation of know-how that is already being applied to the national challenge of new district heating growth.

BIRTH OF THE IDHA

The International District Heating Association (IDHA) was founded in 1909 and has published a quarterly magazine since 1915, whose issues serve as a comprehensive archive for the district heating industry. District Heating issues are indexed by Engineering Index Inc.

The stated purpose of the IDHA is repeated in subsequent issues of the association’s magazine as follows:

The IDHA is committed to "advancement of the art, science, standards and knowledge of district heating; exchange of information pertaining to the management and operation of district heating systems and the utilization of the services; advancement of the mutual interests of producers and consumers of district heat; promotion of economical utilization of the services; and encouragement of a cooperative exchange of information and experience among those engaged in any phase of district heating from production to ultimate use for total space conditioning, including chilled water service. [4]"
In his useful history of district heating, John Collins wrote about the beginning of the IDHA. He noted that the industry had needed some regular way of exchanging and distributing information on the management and operation of district heating systems virtually from the start of the industry. Equipment salesmen shared available information among themselves and with customers, but this was a hit-and-miss communications technique at best. “There was no means of making a permanent record and no definite plan for increasing the fund of knowledge,” wrote Collins. “The old Ohio Electric Light Association held a meeting in the popular old Boody House (with a fireplace in each of its 133 rooms) in July 1909.”

The meeting was attended chiefly by representatives of Ohio power and steam companies. This small group organized an association and planned a district heating convention to be held at the Southern Hotel, Columbus, Ohio in October 1909. A. C. Rogers of Toledo, Ohio was elected the first President of the association. David L. Gaskill, Greenville, Ohio, became the first Secretary-Treasurer at the first year salary of $300.

According to Collins, Gaskill personally financed the association’s initial 87-page Proceedings at a cost of $132, which Collins said was approximately 3% of the cost of issuing a Proceedings in later decades. Gaskill made a survey of district heating facilities in operation 1909–1910 and found close to 150. “It had been thought there were 300 to 400,” wrote Collins and added that Gaskill learned most existing systems were “in the red.”

As early as 1909 the changing nature of American electricity production, the low cost of fuel, and the needs of citizens affected the economic future of district heating negatively. Nevertheless the IDHA remained active and effective continuously to the present.

Collectors of fascinating facts will want to know that Gaskill in 1925 informed the membership that a member of the association under an assumed name had been Nicholas II, the deposed Czar of Russia. The Czar’s interest in district heating showed farsightedness and a practical concern for the energy future of his country. The Soviet Government that replaced him has
RISE AND FALL OF U.S. DISTRICT HEATING

never said anything kind about the Russian Royal family. However, the Soviet Union since World War II has followed Czar Nicholas’s lead by developing one of the world’s most extensive national district heating systems.

John Collins ended his historical survey of district heating by stating: “Some have expressed the thought that district heating has passed its zenith. Quite the contrary is true. While there are not many new steam utilities being organized in the United States and Canada, there has been no appreciable loss. . . . The generation of steam at higher pressures to supply both electricity and steam itself should decrease investment for generation. District heating by hot water has not been looked on with great favor, but the use of high-temperature hot water should increase in the right atmosphere. . . . Finally, in Europe there should be a great increase in district heating. The industry has a bright future.” [2]

In the 1980s the prognosis should be even more favorable for a renaissance in district heating development, but some of the reasons for decline have not been reversed. World petroleum reserves are declining and the end of petroleum as a dominant fuel is foreseen early in the next century, but oil use continues at a fast pace. It costs more now than in the past to live in an American suburb and work in the city, but most Americans are still locked into that pattern. The family automobile costs more now than the family house may have cost in the 1940s or 1950s, and the cost of operating the automobile takes a larger bite from the family income; but there are still plenty of automobiles on the road and bumper to bumper traffic is more the rule than the exception as Americans go to work and return.

In a 1929 book of poems, E. B. White defined the commuter:

Commuter—one who spends his life
In riding to and from his wife;
A man who shaves and takes a train
And then rides back to shave again. [5]

Since 1950, to fit most cases, the verse has needed amending, perhaps as follows:
Commuter—one who spends his life
In riding to and from his wife;
A man who shaves and drives his car
And then drives back to his home and bar.

Either commuter has long been beyond the reach of practical district heating developments. That fact, however, is subject to change under pressure from modern energy prices and constraints. District heating projects are no longer exclusive to large metropolises. Smaller communities such as Piqua, Ohio, Bellingham, Washington, and Moorhead, Minnesota have made commitments to district heating and in 1981 were starting the long process of doing something about it.

FUTURE AWAKENING TO THE PAST

Morris L. Lanning, Mayor of Moorhead, Minnesota, said, “When I took office in January 1980, I identified five major challenges facing Moorhead during the 1980s. At the top of the list was energy. . . . We believe that the most exciting action we have taken is to pursue district heating. At the present time we are wasting approximately 70% of the energy coming from the coal we burn. If we are successful in establishing a district heating system, most of that wasted energy will be utilized to heat over 1,100 buildings. All factors add up to one thing, district heating really makes energy sense.” [6]

The seesaw goes up, and back down it comes. Some focus on the energy sense. Others focus on the cost. Still others say, yes we want energy plants, but we don’t want them here.

Peter McTague in the keynote address at an IDHA meeting said,

If we accept the fact that we have a growing population and that if we are to avoid retrogression in our standard of living, then our economy will have to grow. The conclusion is inescapable that even with more efficient use of electric energy, we will still require very substantial additions of
new power supply facilities. The questions are: Where are those facilities going to be built? How will they be built? And what will be the source of raw energy? . . . Will it be possible to find sites on which new power plants can be built? I know of no specific plant, whether hydroelectric, nuclear, or fossil-fueled, that has been discussed in the last year or so that has not faced formidable opposition. In fact, planning for new power plants has been all but stopped because of special interest opposition to every possible site that has been suggested. Obviously, this does not bode well for new district heating systems either.

McTague is correct that environmental concerns and regulations that reflect them have brought obstacles to new power plant development, and the option of district heating through cogeneration consequently suffers. But district heating itself may help smooth ruffled feathers and eventually give power plants a good name again. Public opposition to pollution from coal-fired plants can be countered with demonstrable proof from numerous European cities that district heating systems in general urban use rapidly promote cleaner air and reduce pollution. In addition to more efficient use of expensive fuel, district heating as part of an electric power plant makes the plant considerably less troublesome as a messy neighbor. For one thing the plant’s greater efficiency means less waste energy and less waste material. Atmospheric discharges of thermal wastes are virtually eliminated with such operations, because what was waste becomes useful heat energy that is regularly distributed to customers.

District heating declined in the United States, though it never disappeared. The factors behind decline are not finished, but warning clouds form on the horizon. Other factors appear to complicate the traditional equation. Some factors that led to decline may be the very ones that bring the technology back into favor on a larger scale than was enjoyed during its heyday.

Lawrence Tuck, Boston Edison Company, Boston, Massachusetts, addressing the IDHA, said, “I believe it is important that we tell the story of district heating in the United States:
the advantages and disadvantages of present systems; the opportunities and pitfalls of transferring European practices to our cities, not to mention the economic plight many of the existing district heating utilities face.”

This is excellent advice. Confronting facts is always an appropriate, scientific way to start any enterprise, whether old or new. Confronting facts is such a useful, worthwhile method, it is surprising how seldom and by how few the method is applied.

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6. “Moorhead, Minnesota, Report from the Mayor, Morris L. Lan
Cogeneration: How It Works

Partnership is a synallagmatic and commutative participation in profits.

Civil Code of Louisiana (1808)

Whatever you cannot understand, you cannot possess.

Goethe

EFFICIENCY IS FASHIONABLE AGAIN

The word synallagmatic is a legal term defined as “imposing reciprocal obligations and characterized by mutual rights and duties.” The word does not define cogeneration, but it is aiming in the right direction. “Partnership” does a better job. “Achieving reciprocal benefits” comes closest to what results in an effective cogeneration arrangement. Synergism is also clearly involved.

The practice of cogeneration occurred in many forms long before the name was attached. According to a U.S. Department of Energy technical report on the subject, “In broadest terms, cogeneration denotes any form of the simultaneous production of electrical or mechanical energy and useful thermal energy (usually in the form of hot liquids or gases). Cogeneration systems include dual-purpose power plants, waste-heat utilization systems, certain types of district-heating systems, and total-energy systems.” [1]
District heating systems are examples of cogeneration when an electric utility or industry with its own power plant supplies thermal energy in the form of steam or hot water to customers. When a district heating system does not involve electrical generation but simply the burning of fuel to supply heat, cogeneration does not occur.

Total energy systems, such as the system operated by the Regency Square Shopping Center, Jacksonville, Florida, produces electricity, heating, and cooling, typically for a compact development such as a shopping center, medical complex, university campus, or comparable institutions.

Traditional energy systems in the United States have ordinarily delivered only one product, either electricity or heat. When cogeneration is introduced, one system is designed to deliver both electricity and thermal energy, with a substantial improvement in fuel and operational efficiency as a result. In a cogeneration operation, thermal energy that would otherwise be discharged as waste is put to use. This can make a system significantly more efficient than before in terms of energy savings and reduced fuel requirements.

Cogeneration offers the following benefits:

- **Flexibility in the use of fuels:** Various alternative fuels in plentiful supply can be used rather than oil and natural gas.
- **Efficiency:** National energy self-sufficiency is promoted, because energy waste is eliminated or reduced.
- **Cost advantage:** By using less fuel to achieve objectives, cogeneration saves both energy and capital.
- **Environmental Improvements:** Cogeneration systems need less fuel to produce a stipulated amount of energy, which means a corresponding reduction in the pollutants released as a consequence of burning fuel.
- **Resource Conservation:** By achieving more with less fuel, cogeneration saves depletable fuel resources as well as the energy that would be required to extract and deliver those resources.
• Dependability: Reliable power is more likely to be available during periods of emergency such as natural disaster, adverse weather, or a local blackout.

For several decades cogeneration was known about as a means of conserving energy, and all the above advantages were recognized, but little was done to introduce cogeneration. Deliberately wasting energy was a predictable result of cheap energy supplies.

In the 1980s conventional energy supplies are less easy to acquire, less certain, and their prices are much higher. In the United States, cogeneration as a result is beginning to be noticed rather than ignored. Saving fuel, reducing expense, protecting the environment, and assuring reliable power have become important goals only cogeneration can effectively reach. The technology of cogeneration is not new, since various forms of it date back to the 19th century. This familiarity is itself an advantage, because delays for research and development are not necessary before implementation.

“Cogeneration is a viable technological alternative that offers the United States one more strategy for working toward its goal of energy self-sufficiency both now and over the long term,” stated the Department of Energy report on cogeneration.

Two basic types of cogeneration systems are available: (1) topping system, which produces electricity and exhausts thermal energy which is used for district heating or comparable functions. (2) bottoming system, which produces thermal energy for an industrial process or district heating and part of the thermal energy is withdrawn to generate electricity. Each system has particular equipment requirements. Which system is used depends on the special needs and situation of the user.

Utilities commonly supply district heating steam or hot water through a topping system. Institutions, shopping centers, and similar complexes as well as industries may first need steam for heating/cooling or process operations, and find it expedient to drive a turbine with a fraction of the steam to supply electricity in a bottoming operation.
Figure 5-1. Cogeneration serves university campuses. Georgetown University in Washington D.C. is one among many American campuses expecting district heating and cogeneration to keep the halls of learning warm and lighted during coming decades. Georgetown’s “fluidized bed” boiler will be the main source of energy for campus buildings and residences. Coal is burned in a limestone bed to remove sulfur. Cogeneration of electricity and steam is the long-range plan. You’ll find the facility at the end of Prospect Street in Washington D.C.
Georgetown University, for instance, installed a fluidized bed, coal-fired boiler to supply heat on the Washington, D.C. campus. The coal is burned in a bed of limestone to remove sulfur, which allows eastern high-sulfur coal to be used. When a turbine is added to the system, Georgetown University can also produce its own electricity. Dennis Shaff, Director of Contracts in the university’s physical plant told the author, “A small increment of additional energy will be used to produce electricity, but energy efficiency from the coal will be greater. Using the turbine for cogeneration enhances the economics of the facility. Our studies showed it is cost-effective and a reasonable add-on. We are strongly behind the cogeneration step.”

**TOPPING SYSTEM**

Thermal energy left over from generation of electrical or mechanical energy is available for industrial applications or district heating and cooling. A thermal-to-electrical conversion can be made with a “heat engine,” which is also known as a “prime mover.”

Steam turbines, gas turbines, and diesel engines are three common heat engines associated with topping operations.

As the prices and availability of oil and natural gas worsen into major problems, having heat engines available that can employ various alternative fuels is critically important.

The steam turbine has such flexibility, since its boiler will generate steam through combustion of natural gas, oil, coal, liquefied coal, biomass, and synthetic fuels. This versatility makes the steam turbine a popular choice for future cogeneration in the topping mode.

In the steam turbine, high pressure steam produces mechanical energy which is converted to electricity by means of the generator. When this primary function is accomplished, the remaining low-pressure steam is available for other services including industrial processes and district heating.

Neglecting to recapture this excess steam was commonplace
in America during recent decades. With cheap oil and gas conveniently available, there was no ready market for the surplus energy which was consequently dissipated as waste. Now energy conditions in the United States are at or approaching the point where the reverse is true, with a market both ready and willing to use the surplus energy if and when it is made available and delivered in a usable form.

In gas turbines and diesel engines, combustion gases from burning fuel drive a shaft which in turn drives the generator to produce electricity. This contrasts with the use of steam to produce mechanical energy at the start of the generating process. A limitation with gas turbines and diesel engines has been their requirement for natural gas or oil as operating fuels. The logical goal with future cogeneration operations is to reduce dependence on such premium energy sources. For this reason, cogeneration with gas turbines and diesel engines so far has been secondary to steam turbines, although the energy savings with the former are potentially greater than with the steam turbine.

Thermal exhaust from gas turbines and diesel engines can also be used to serve a number of purposes as in the case of the steam turbine. Among leading applications for this exhaust are generation of process steam or direct use of the exhaust for process heat. When steam is produced with such systems, exhaust gases pass their heat energy to water in a waste-heat-recovery boiler. With the exhaust gases as boiler fuel, the water is converted to high-pressure steam.

If this steam is fed to a steam turbine, it produces more electricity in a "combined cycle."

**BOTTOMING SYSTEM**

This process is generally associated with the combustion of fuels to produce the high temperatures required in various industrial processes. Examples of representative applications are aluminum remelt furnaces, glass kilns, and steel reheat fur-
HOW IT WORKS

naces. The hot exhaust typically is passed through a waste-
heat–recovery boiler where the heat vaporizes a fluid which
can be used to deliver mechanical energy or produce electricity.
In a closed-loop operation, the vapor stream gives up its
heat and returns to the liquid form. It is pumped back to the
waste-heat–recovery boiler for continuous repetition of the
procedure.

Water can be used as the fluid in bottoming systems, although
organic fluids such as toluene are more flexible. Some organic
fluids can be used at temperatures lower than the vaporization
temperature of water, and they give superior efficiency at high
temperatures. Because of the “liquid to vapor” cycle, the sys-
tems are known as “phase-change” systems. They are also called
Rankine systems.

According to the Department of Energy report, “Current
technologies for both topping and bottoming systems offer sub-
stantial potential to save conventional fuels. The equipment
needed is available, and the concepts are proven. A variety of
approaches to cogeneration based on topping and bottoming
techniques can be pursued.”

COGENERATION APPLICATIONS

The Department of Energy identifies three major markets
in the United States for cogeneration development: 1) the in-
dustrial sector, 2) residential/commercial/institutional sector,
3) utility sector.

Factors that determine the design and type of cogeneration
system developed for specific applications include:

• electrical requirements
• thermal requirements (e.g., process heat or steam, district
  heating and cooling)
• operational cycle (time of day customer energy demands
  reach their peak)
• available fuels for cogeneration operation
• equipment and hardware considerations
• regulatory considerations
• distance of potential users from the generating plant (steam
district heating is limited to users within a five mile radius
of the plant; hot water district heating is effective for
much greater distances)
• potential arrangements with local or regional utilities

THE INDUSTRIAL SECTOR

Industrial cogeneration often involves an arrangement to
deliver excess electricity generated in the system to the electric
grid. Using a grid in this manner to make unneeded electricity
from an industrial plant available to other private electricity
users is called "wheeling." With such provisions, the cogenera-
tion operation need not maintain extensive standby equipment.
Mechanisms and regulations are in effect in the United States
to encourage such developments, thus further reducing energy
waste. Providing for the redistribution of excess power through
the grid helps assure that power generating potential is not
neglected simply because there is nothing to do with the power
once the needs of the cogeneration system are met.

When an effective energy partnership of this sort is set up
between a utility and an industry with cogeneration capability,
substantial cost and fuel saving benefits result. Utilities provide
a valuable service to industry and achieve efficient energy utili-
zation through this approach, and the utilities themselves may
also be well served. By purchasing excess industrial power,
the utility could thereby fill peak load demands without falling
back on less efficient equipment to generate additional power.

The ability of an industrial cogenerator to sell or buy elec-
tricity through the grid frees industry from concerns about
outages and makes cogeneration more attractive as a reliable
and profitable company operation. Yergin wrote,

One aspect of industrial conservation stands out, for Ameri-
can industry has within its grasp an Alaskan oil strike, a
major new source of energy waiting to be developed. This type of conservation energy deserves special attention because of its potential scale and because its availability largely depends upon requisite decisions being made in the political process. The source is sometimes called combined heat and power, a term awkward enough to be designated CHP, and perhaps for that reason better known in the United States as cogeneration, but the meaning is simple enough—the combined production of electricity and heat (the latter for either process or space-heating purposes). [2] During the 1970s as the so-called “oil crunch” developed, recognition of the benefits available through industrial and utility cogeneration spread widely. A 1974 Ford Foundation report argued the merits of cogeneration which seeks to improve efficiency by producing both steam and electricity together. When electricity is produced alone, only about 30 to 40 percent of the fuel is converted to electricity; but in combined systems, about 80 percent of the fuel energy can be used to produce both steam and electricity. Large savings result when the electricity is generated near the industrial plant so that the waste heat that would pose a thermal pollution problem at a central power station can be put to use for industrial process steam. The net savings in total energy requirements for steam and electricity can be about 30 percent. . . . There are good reasons why most industries should consider self-generation of electricity, either at new locations or at existing sites, wherever feasible. Such on-site power generation as a byproduct of steam production at industrial installations appears to be practical and economical on a wide scale. [3] The logic of self-reliance has an increasingly broad appeal among industrialists. Some American industries such as Dow Chemical Company were taking this advice many years before it became fashionable enough for attention from prestigious foundations. In a subsequent chapter on past, present, and future U.S. applications of cogeneration technology, the Dow case
will be described in detail, as well as other examples of industrial cogeneration now active or planned for the United States.

THE RESIDENTIAL/COMMERCIAL/
INSTITUTIONAL SECTOR

Standard technical, physical, and sizing considerations are in effect for this market as they are for the industrial sector. The design and type of cogeneration system again must be determined on the basis of electricity and heat requirements, fuel costs, peak demands, and similar concerns.

Independent systems known as "total energy plants" can be developed which may or may not be hooked to utility grids. If the cogeneration operation is not connected to the grid, the plant can either be completely on its own, or as a precautionary measure, it may arrange to buy power from the utility in case of shutdown.

Big shopping centers, development complexes, housing projects, medical centers, research parks, and other large, integrated institutions such as university campuses, offer practical sites for cogeneration of heat and electricity.

Ideally cogeneration is introduced at the start of the facility rather than expensively retrofitted later. During the design, planning, and construction stages of new developments, fuel-efficient cogeneration and district heating arrangements may later save millions in operating expenses. This approach has been followed at developments around the country. With steadily rising fuel costs, the practice is expected to accelerate.

At King's Plaza Shopping Center in Brooklyn, New York, a total energy plant was designed to supply the center with electricity and steam for heating. In 1981 the center could use either oil or gas as fuel, and was burning gas as much as possible because of an economic advantage. King's Plaza had not arranged to deliver excess electricity to a utility grid as in the case of Regency Square Shopping Center, Jacksonville, Florida. Cogeneration has meant steady energy savings in the shopping center's
operations. The plant has paid dividends in energy management and cost control according to the operations and property manager in a conversation with the author.

Franklin Heating Station, Rochester, Minnesota, as reported by the Department of Energy [1], does have a connection to the utility grid. Since 1927, this facility delivered steam and electricity through cogeneration to the Mayo Medical Clinic and the Kahler Hotel. The Department of Energy report on this operation states, "The Franklin Board, which consisted of representatives from both Mayo and Kahler, soon recognized the potential advantages of co-owning a reliable source of power and at the same time maintaining a tie with the municipal grid to purchase any additional needed power. This arrangement has proved to be highly successful."

In 1975 Rochester Methodist Hospital became a third recipient of heat, air conditioning, and electricity from an efficient, long-running operation.

Many university campuses have turned to cogeneration as an effective and cost-efficient means of supplying the energy needs of classrooms, buildings, laboratories, and libraries. Texas A&M University, College Station, Texas functions similarly to the Franklin Heating Station arrangement through a connection to the local utility.

Some universities have relied on cogeneration for years; others are considering it as a future move. What was uneconomical with low fuel and electricity prices, becomes urgently worthwhile as oil prices climb beyond $30 a barrel and electric rates soar.

Previously cited Georgetown University made a commitment to cogeneration late in the 1970s. Michigan State University at East Lansing, Michigan was much earlier in meeting the heat and power needs of its large central campus through an elaborate cogeneration and district heating system. The Michigan State power plant features elaborate modern control mechanisms in a highly sophisticated heat-power operation.

Ohio State has a plant for district heating service on its main campus in Columbus, Ohio. The facility supplies warm water
at temperatures ranging between 38° and 93° C depending on ambient temperatures. Ohio State, the same as Michigan State University, is a large campus. Cogeneration, however, is not limited to big institutions. Bowdoin College, Brunswick, Maine, operates a campus steam service and recognizes the growing value of adding electric generation as a way to save fuel, reduce costs, and supply power to the computer that controls energy distribution and use on the small campus. Roland West, Manager of Engineering at Bowdoin College, said the institution would seriously consider cogeneration some time in the future, possibly with an agreement to deliver some electricity to the utility grid. West noted that other New England campuses are evaluating similar developments to meet their energy needs more efficiently.

THE UTILITY SECTOR

Measured by total assets, electric utilities constitute the largest American industry. The cogeneration concept has not been extensively applied by utility members of this industry in the United States, although a few large power companies serving central city areas still maintain long-standing district heating operations for steam customers. The five leading power companies measured by the volume of their district heating sales are:

- Consolidated Edison of New York (40% of U.S. steam sales)
- Philadelphia Electric
- Detroit Edison
- Boston Edison
- Indianapolis Power & Light

Details on individual utility cogeneration operations are provided in other chapters. American utilities in recent years generally have been cautious about cogeneration arrangements and
district heating developments because of comparatively low profits, and even losses, on their steam sales. Walter McCarthy, President of Detroit Edison, told the North Central States Conference on District Heating, that “in general district heating makes only a small contribution to utility operations, and attitudes in the industry tend to be negative about expansion of old or installation of new systems.” [4] However, despite reservations, Detroit Edison is proceeding with plans to expand its existing district heating activity and to upgrade steam service that has continued in the core area of Detroit since 1903.

One reason the Detroit cogeneration system has been able to continue operating while others in the United States closed down was the presence in Detroit of large industries that gave the utility steady customers for process steam. Without industrial customers, few utilities at this stage could operate profitable district heating systems for residential and commercial users.

Nevertheless, conditions have been suitable for long-running district heating programs in various cities across America—cities widely separated climatically, geographically, and economically.

For more than 60 years, San Diego Gas and Electric has sold steam in downtown San Diego to heat apartments and offices.

For more than 50 years, Gulf States Utilities has maintained a cogeneration operation at Baton Rouge, Louisiana. An Exxon petrochemical plant has helped this cogeneration effort succeed by taking 3 to 4 million pounds of steam per hour.

Philadelphia Electric Company for more than 30 years has supplied low-pressure steam to the City of Philadelphia.

Many other examples could be cited of cogeneration activities that have kept going through good management, and of course, the good fortune of having appropriate customers available. The Department of Energy explained why some utility cogeneration operations closed down in the United States:

Most of these have been systems that supplied heat to a large number of residential and commercial facilities rather
than to a limited number of industrial users. The main reasons for this decline seem to be related to the use of steam as the heat-transfer medium. As electrical-transmission technology improved, it became possible to accommodate public preference by locating large plants in less densely populated areas. Because steam cannot be transported economically over long distances, many utilities were forced to discontinue their cogeneration operations. [1]

Future prospects for utility cogeneration are stronger as a result of fuel shortages, costs, and a manifest national need. Utilities and consumers already are discovering mutual benefits in extracting maximum energy from minimum fuel. Utilities supplying cogenerated steam to nearby industrial or institutional customers may prove one of the most lucrative and extensive cogeneration approaches. Contemporary examples abound. "An Exxon refinery in New Jersey. . . . buys its steam from a power station a mile away, just as Harvard buys steam from a generating plant on the Charles River," wrote Yergin. "Other firms and power plants are exploring such symbiotic relationships." [2]

Cogeneration of heat and electricity by industries, institutions, and large developments will be an important, indeed vital contribution to energy conservation during coming years. However, participation of utilities in cogeneration is considered indispensable to the long-term success of the technology in the United States. Utilities have the customer networks, the know-how, and the thermal energy output necessary for district heating development or the delivery of process thermal energy to industrial customers. Utilities also share with the rest of the United States a compelling mandate to conserve any way and every way possible.

Retrofitting existing electric power plants to provide steam for district heating represents a major opportunity to conserve energy and thus a leading challenge in the effort to broaden the use of cogeneration and district heating nationally. When new power plants are constructed, designing them for cogeneration offers the ideal approach; but many older power plants
will be consuming energy and producing electricity for many years. Upgrading the fuel efficiency of these operations is a prime objective. Many of the currently active district heating projects in the United States directly involve studying existing plants and finding effective ways to retrofit them for cogeneration district heating.

Figure 5-2 schematically shows a power plant suitable for district heating cogeneration, while Figure 5-3 offers a simplification of the steam-electric conversion part of a 150 MW

**Figure 5-2. Schematic of a steam-electric generating plant with district heating potential.** Exhaust steam from the extraction back-pressure type high pressure turbine is reheated in the boiler reheater and then goes to the intermediate pressure turbine. The subsequent crossover from the intermediate pressure turbine to the low pressure turbine provides an opportunity for retrofitting to deliver steam for district heating. Retrofit could also be designed to supply hot water for district heating purposes. If steam is diverted for district heating, there is a loss in electrical production; but the overall efficiency of the operation is increased. Other diversion points for extraction of thermal energy are available in the system.
Figure 5-3. *Simplification of steam-electric conversion in a 150 MW plant.* This is a representative configuration involving high-pressure, intermediate pressure, and low pressure turbines. Thermal energy for district heating can be extracted through retrofitting. At the IPT to LPT crossover, up to 70% of the steam could be withdrawn. Since this would reduce electrical generating capacity, a balance must be effected between electric and district heating needs when retrofitting existing power plants for cogeneration applications.

plant, representing approximately the electric needs of a city with 40,000 to 50,000 residents.

Retrofitting willy-nilly without carefully analyzing electric as well as district heating needs would be a potentially costly mistake. Since retrofitting power plants for cogeneration district heating will be large-scale and expensive projects, they are never likely to be done impetuously.

The merit of performing necessary studies and moving ahead is clear, however. Most utilities around the United States on a day-to-day basis are functioning at little more than 30% fuel conversion efficiency (100% fuel burned, 30% electricity delivered). Contemporary energy facts-of-survival make this a situation to alter if reasonable options are available. District heating by means of cogeneration through retrofit alterations of existing power plants now qualifies as an option and rising energy prices make it increasingly reasonable, with the possibility in time of becoming imperative.

Considering present energy losses at most U.S. power plants, the potential energy savings are enormous.
REFERENCES


THE OLD SCIENCE OF STRETCHING FUEL

District heating is not a complicated technology. It is quite simple technically which should be an eminent virtue in its favor. Yet ironically simplicity may be an obstacle to acceptability among energy decisionmakers conditioned and mindset to consider complexity and efficiency synonymous. An important goal for advocates of district heating is to reeducate the experts into recognizing that an uncomplicated, elderly, straight

How many wheels must we replace before we stop making them square?

Amos B. Gwin

1
At several piquant moments in history—the latest of them today—wise observers of the energy scene have bemoaned the absurdity of having to rediscover and reinvent what should have been practiced continuously. . . . Today, then, we stand precisely in the place several earlier cultures have stood. We have suddenly learned the transitory and ephemeral nature, the vulnerability, and the high social, ecological and even economic costs of depending on nonrenewable hydrocarbons to hold our societies together. . . .

How many wheels must we reinvent before we stop making them square?

Amory B. Lovins [1]

THE OLD SCIENCE OF STRETCHING FUEL

District heating is not a complicated technology. It is quite simple technically which should be an eminent virtue in its favor. Yet ironically, simplicity may be an obstacle to acceptability among energy decisionmakers conditioned and mindset to consider complexity and efficiency synonymous. An important goal for advocates of district heating is to reeducate the experts into recognizing that an uncomplicated, elderly, straight-
forward, "elementary my dear Watson" type of technology isn't necessarily obsolete, old-fashioned, and inappropriate for the modern era. The fact district heating has been a fact over a century does not in itself render the technology "nonmodern." Today energy realists should resolutely seize any energy methodology from Stone Age times to the present, proclaim it modern, and put it to work if more feverishly needed Btus are thus obtainable. The modern rush to find and burn wood—man's first and oldest fuel—attests to the truth that the techniques of antiquity are just as good as ever.

Expressed in plainest fashion, district heating is a basic method of supplying heating or cooling for space conditioning and related applications with the key goals of getting more benefit from fuels burned, reducing environmental pollution, and saving money. Modern men are skilled in arguing among themselves about virtually everything, but these are fundamental desiderata all can approve though they wrangle incessantly about how to achieve them.

An assessment of district heating in Science magazine by Karkheck et al. reported, "District heating has the advantage of being a proved technology in Europe. It requires simple hardware, and is reliable and simple to operate... Many American cities exhibit characteristics similar to those in Europe where district heating now serves a significant portion of the populace and will expand to virtually the entire populace in the near future." [2]

The cogeneration opportunity with district heating was summed up by Karkheck: "In many situations waste heat from electrical generation plants or industry could be used to meet residential and commercial space and hot water energy demands with resultant large savings in the oil and gas resources now consumed for such purposes."

District heating did not flourish during the last 35 years in the United States as it did in Europe. Some reasons have been discussed—changed lifestyles, the creeping triumph of suburbia, utility siting at a distance from urban centers. Another reason was the fact individual house and apartment dwellers could
heat living spaces and hot water with natural gas or independent residential systems less expensively than district heating, thanks to cheap and plentiful fuel.

Although district heating during this period did not catch on in America, the technology boomed in Europe, with many metropolitan systems started during the large-scale rebuilding effort following World War II. A survey in the 1970s by the United National Economic Commission for Europe found 25 percent of total electrical-power needs in conjunction with district heating cogeneration were supplied for the following: Bulgaria, German Democratic Republic, Federal Republic of Germany, Poland, Rumania, Austria, Denmark, Finland, Sweden, Yugoslavia, the USSR. [3]

Yergin wrote,

> Cogeneration can take two forms. In the first form, steam (or hot water) from a power station is delivered by pipes to homes and offices to provide heat and hot water. Such systems, called district heating, are quite common in both Eastern and Western Europe, with about a thousand in the nine countries of the European community. District heating schemes, however, are economical only when urban density is high and subscription to the system general. Up to now it has been thought that, for most American cities, the cost of putting in the pipes and other parts of the system would be prohibitive, although recent studies for St. Paul and Minneapolis have suggested a more promising potential. [4]

(The second form of cogeneration identified by Yergin involves production of steam and electricity at industrial plants using the topping cycle.)

The 1977 analysis by Karkheck, *et al.*, showed that 50–55 percent of the U.S. population could be economically served by district heating. That estimate was based on prevailing oil prices at the time. Substantially higher prices now give district heating an improved position economically. The authors estimated a total investment in U.S. district heating systems to serve this
large market at $180-billion, with resulting oil conservation reaching $1.1 \times 10^9$ barrels annually (then about 55 percent of imports). Reduction in foreign payments would exceed $12-$
billion annually. “In terms of national benefit, the district heating scheme would pay for itself after 14 full years of operation at maximum implementation, or sooner if imported crude oil were to increase in price.” [2]

Imported crude oil did increase in price, and the economic rationale for district heating in the 1980s looks even better than it did. Inflation, of course, has also substantially hiked the cost of starting up or retrofitting district heating systems, and the $180-billion figure clearly is a modest one today. More, much more, would be needed. Yet even so, the payback period for district heating systems is still realistically and manageably brief for cities willing to begin paying now in order to warm themselves later.

European countries after World War II built large, complex, efficient district heating systems. Most of these were built and controlled by the governments involved. U.S. district heating development is also likely to require state and federal support in order to approach full potential. Both regulatory and financial backing will probably be needed to stimulate the introduction or revival of city district heating projects. User-owned central heating systems in the Residential/Commercial/Institutional sector are more likely to be independently built as developers and operators, the same as homeowners, seek ways to reduce or at least control energy costs.

An estimated 55–75 percent of district heating capital requirements is used in constructing the transmission and distribution network—in other words, putting in the “plumbing,”—installing pipes through cities and outfitting customers with requisite equipment.

The heavy burden of startup costs should experience some relief in the United States as technical progress is gained in the main area where technical improvements are seriously needed—putting in the pipes. District heating economics will improve when low-cost nonmetal pipes and faster, cheaper installation
technology are developed. Such technical advances are the subjects of continuing European research. When the U.S. enters the field in massive earnest, better materials and methods could be expected. The simple district heating concept works smoothly and reliably just as it did in Birdsill Holly’s day, but relatively little progress has been made in installation methods—except use of power tools and better equipment—since engineer Charles Emery and his night team strung district heating pipes through downtown Manhattan in 1880.

DISTRICT HEATING BY ANY OTHER NAME

“What’s in a name” asked Juliet and lived to regret it. District heating is not the most accurate or descriptive name for the technology considered here, but it is the name that apparently has won the international competition. Half a century ago, J. H. Walker, Superintendent of Central Heating, Detroit Edison Company and a major contributor to the 1924 second edition of the authoritative District Heating Handbook published and updated at intervals by the IDHA, defined central heating as “supplying of heat to a number of separate buildings from a central plant. When portions of a city are thus heated the term district heating is often synonymously used.”

When district heating systems are developed, all the heating equipment in individual buildings generally is replaced. This requirement is the main concern from a user’s viewpoint. Once the system is installed, the user typically will find his life simpler and easier than before. Keeping individual furnaces fueled and operating becomes only a memory.

A range of options is available for producing heat and using it in district heating systems. The three heat producers are:

1. Steam or hot water taken directly from the boiler and distributed to district heating customers.
2. Steam passed through an extraction or back-pressure turbine (designed for electricity and heat production) and
then distributed directly or converted to hot water for distribution.

3. Steam extracted from a modified electric generating plant with condensing turbines.

The three variations available for energy use are:

1. Thermal loads satisfied from nonelectric sources.
2. Thermal loads satisfied by electric resistance heating.
3. Thermal loads satisfied by electrically driven heat pumps.

The heat producer and energy use configurations can be combined in nine different ways. Producing steam or hot water without electrical generation is done in Europe and parts of the U.S. This is a method that avoids the political and institutional headaches often afflicting electrical utilities, but it has the disadvantage of being the least effective method for energy conservation, a prominent objective of district heating development. Some benefit in this respect can be gained from economies of scale and the use of cheaper fuels.

HEAT AND ELECTRICITY VS. ELECTRIC-ONLY

Burning municipal refuse and sewage sludge to fuel a district-heating-only operation is a growing trend in Europe and much talked about in the U.S. Indianapolis Power and Light has supplied steam to commercial, residential, and industrial customers through most of the 20th century. A future prospect identified by this utility to keep district heating competitive is development of a municipal refuse energy-conversion operation. A similar project is in the planning stage at Detroit Edison where it is estimated that a refuse burning plant producing steam and hot water for district heating could supply 50% of the annual fuel required for Detroit's future district heating system when hypothetical expansion occurs.

From an energy conservation viewpoint, the ideal configura-
tion for a district heating system involves cogeneration of heat and electricity. (Figure 6-1) Traditional steam-electric plants without district heating are only about 33 percent efficient in converting fuel to electricity, with 67 percent of fuel energy lost as waste heat up the stack or in the plant itself. [2] Released into the air, this waste heat can do environmental harm to rivers and lakes in the vicinity.

Karkheck et al. estimated that when waste heat from a steam-electric plant is used for district heating, an overall energy conversion efficiency of 85 percent is conceivably attainable. “Nuclear power plants operating in the dual mode offer higher efficiency (95 percent) and greater fuel savings because of the lack of stack gas losses,” Karkheck wrote.

In one cogeneration mode, greater total plant efficiency is achieved because cogeneration eliminates the condensing of steam and rejection of heat in the condenser, which consumes as much as half of the energy context in boiler fuel.

One district heating cogeneration technical feature that has partially inhibited district heating development in the United States, where demand for electricity has sometimes exceeded the ability of utilities to supply it, involves the reduction in electrical output that occurs when an existing turbo-electric generating plant is converted to district heating cogeneration. The loss of electric generating capacity is more than replaced by the thermal energy made available for heating applications, but utilities hard-pressed to meet electric demand have resisted the change.

A district heating system replaces the use of gas and oil for direct home heating purposes and may displace such heat sources as heat pumps and electric resistance heating. Figure 6-2 shows district heating and electricity cogenerated with optimum efficiency (28% electricity output, 80% efficiency achieved by delivering thermal energy for district heating or cooling). This compares with 67% of the heat lost to the environment in the electric-only plant.

In practice, the heat from a cogeneration plant may not always be fully utilized by district heating customers which
Figure 6-1. *Total energy district heating*: the cogeneration efficiency of a total energy system plant is potentially high, resulting from elimination of the waste energy involved in condensing steam in the condenser. Using high pressure steam from the turbine does reduce electrical output from a given amount of steam. Success of the system necessitates a high average requirement for steam so the efficiency features of the system can achieve optimum results.
Figure 6-2. Efficiency of the cogeneration power plant compared with an electric-only power plant. Cogeneration achieves 80% fuel efficiency versus 33% in the electric-only plant.

lowers efficiency significantly. For this reason, successful cogeneration district heating operations are commonly found in areas where large populations and varied activities will consistently absorb the bulk of thermal energy made available.

The recent extension of district heating to include absorption air conditioning service helps systems achieve year-round operating efficiency. Systems probably benefit most from the availability of industrial customers with year-round rather than seasonal needs for process energy.

Indianapolis Power and Light, with a system capacity of 2,100,000 pounds of steam per hour, has operated successfully
over a long period because local industry and a university campus take large quantities of steam on a continuing basis. The rest of the system’s 620+ customers include commercial and residential steam users in the city’s business district and adjoining areas. Industrial customers, the secret of success in this operation, include a metal processing plant, hospital laundries, meat packers, and manufacturers of pharmaceuticals, corn starch, and corrugated boxes. A representative of Indianapolis Power and Light told the author that his company and Detroit Edison tend to have the highest load factors in the district heating industry because manufacturing and other industrial activities are close at hand with steady requirements for process steam.

STEAM VERSUS WATER

Steam has been the main thermal medium supplied by district heating systems in the United States. This was true from the start of district heating in America, but it runs counter to the prevailing practice in the rest of the world.

The Department of Energy in a report on cogeneration considers the U.S. emphasis on steam district heating, primarily to supply industrial process needs, is one reason utility cogeneration has been less successful in the United States than in Europe. The Department of Energy publication offers two explanations: [3]

1. Europeans primarily use hot water instead of steam as their heat supply medium.
2. European utilities are smaller and more decentralized than in the United States.

"The use of hot water offers several important advantages over the use of steam," the report states. "First, hot water can be obtained as a byproduct of power generation at a much
lower fuel cost. Second, both the rate and temperature of heat supplied in the form of hot water can be varied easily. The ability to vary the supply temperature without cutting back on electricity production eliminates the requirement for heating loads to be consistent throughout the year. Third, because hot water has a greater heat-storage capacity per unit weight or volume than steam, hot-water systems are able to service larger areas. In view of high fuel costs and varying seasonal heat requirements, the advantages of using hot water as a medium in cogenerated district heating are overwhelming in Europe.”

A preference for hot water district heating is also evident in American cities planning new district heating operations.

STEAM DISTRICT HEATING

Sheldon D. Strauss in *Power* noted that district heating cogenerated by a new power plant achieves fuel efficiencies up to 80% contrasted with 39% at the best single-purpose generating facilities. Existing power plants, if retrofitted for cogeneration of steam, reduce heat loss to about 25% while slightly decreasing the plant’s electric output.

“Retrofitting is required,” Strauss wrote, “because most plants in the U.S. are not designed for extraction of the large amounts of steam required for district heating. Plants are generally the condensing type, with 60–65% of throttle steam flow going to the condenser. In retrofit schemes, the steam is extracted from the turbine stages before reaching that point.” [5]

U.S. district heating systems began with steam—as in New York City during the 1880s—and continued with steam because their city customers were accustomed to it, the equipment was in place, and it would have been prohibitively expensive to switch. Europeans built many of their district heating systems from scratch after World War II and had an opportunity to take advantage of hot water’s technical superiority for citywide district heating systems.
The leading U.S. district heating systems, associated with large electric utilities, have supplied steam continuously for most of the 20th century. These systems will continue to deliver steam, although system improvements in time might include hot water service as well. Detroit Edison’s improvement program includes consideration of hot water service when municipal refuse becomes the dominant fuel for heat generation.

One convenience aspect of steam systems is the need for minimum user equipment, since there is no arrangement or piping for condensate return as in most hot water systems. [6] Steam systems can be added to buildings with hot water systems through the use of surface heat exchangers. Steam is preferred for industrial processes, hospital sterilization, commercial laundries, and food preparation. Steam is needed for absorptive air conditioning systems. These established needs will probably keep steam service available where it exists.

Approximately 45% of industrially consumed energy in the United States produces process steam. When industrial customers are available and maintain consistent steam requirements, steam district heating attains the highest level of success for district heating in the United States. The technical advantages of hot water can’t argue or persuade in the face of success.

In comparison with hot water systems, steam systems offer less heat capacity, reduced geographic scope, operate at higher temperatures, and require steam traps. Despite drawbacks, steam district heating continues to have its customers and its champions in the American market.

The Department of Energy report on cogeneration summarized the position of U.S. steam advocates: “The use of steam as a supply medium has several advantages in the United States: air-conditioning plants (which are used far more extensively in the United States than they are in Europe) operate more efficiently with steam; industrial customers prefer steam; and because the condensate that remains after steam has been used does not have to be returned, distribution systems are less expensive.” [3]
HOT WATER DISTRICT HEATING SYSTEMS

What may be developing into a U.S. trend and what already is the European practice involves the use of hot water as the final heating medium. The most ambitious district heating program for the 1980s is the Twin Cities Project at Minneapolis and St. Paul, Minnesota. The ultimate goal of the project is to supply space heating and domestic hot water from a coal-fired power plant supplemented by peak heating plants. The distribution system will deliver hot water to high and medium density commercial, institutional, and industrial users.

Studies in the area established that it has model characteristics for district heating: a cold climate, concentrated populations, dependency on imported oil and gas, the existence of coal-fired plants suitable for cogeneration with hot water as the district heating medium. The first stage of the project which will take several years has the primary goal of a hot water district heating system in St. Paul. George Latimer, St. Paul’s Mayor, said in 1980, “We set up a not-for-profit district heating corporation. Everyone cooperated, because energy is too important for partisan politics. We knew we couldn’t wait for it to happen. We had to make it happen. In St. Paul we’d rather not wait. District heating is needed as soon as we can get it.”

Hot water systems normally have feed and return piping plus pumping stations to maintain pressure. Hot water systems are not easy or inexpensive to retrofit in buildings now using steam. Also hot water systems require the installation of pumping systems to serve the upper levels in tall buildings. Advance planning for hot water district heating service in new structures is advisable to avoid the greater costs of installing hot water systems later.

Hot water systems deliver heat as much as 60 miles from the central station. This figure dwarfs the 2-3 mile limitation of steam systems.

Pipes for hot water distribution are smaller and therefore
less expensive than steam pipes for comparable loads. A hot water system is simpler and less trouble to maintain than a steam system. Hot water can be used at a broad range of temperatures and stored in accumulators for delivery at peak demand periods.

Greater efficiency and flexibility make hot water systems preferable for new district heating developments. However, in the United States steam service will still be required by industry and in other established applications. Both steam and hot water district heating are likely to continue or develop in the United States to satisfy special needs and conditions, with choices based on specific applications and relevant characteristics of the two competing district heating methods.

METERING THE DISTRICT HEATING SERVICE

A key part of any energy supply technology is developing a consistent and fair method of measuring the quantity of energy delivered for customer charge purposes. No one yet has found a successful way to meter and then charge for the air we breathe, but metering science and district heating came together long ago.

Use of a mechanical heat flow meter is recommended for large consumers receiving hot water. "It is far more difficult to measure the heat supplied in the form of hot water accurately and cheaply than it is to meter steam," wrote Norman R. Taylor. [7]

Mechanical heat flow meters are costly and hard to install in the smaller dwellings that make up the bulk of district heating customers. One practice is to use a mechanical heat meter to determine the heat going to a group of customers (as in a housing complex), and to install less precise, smaller meters in each individual residence to determine approximately how much of the total energy an individual recipient consumed.

A number of metering techniques and instruments are available. Simple water flow meters are used in Holland to measure
the water flowing into each dwelling and the figure is used to calculate heat consumption and assign charges. This metering system is inexpensive, easy to use and interpret.

Two types of evaporation meters are available. One measures the heat given off by radiators; the other measures the hot water used in the kitchen or bath.

Radiator type meters may be placed on each radiator in a dwelling. The graduated meter tube functions through the course of a heating system by the evaporation rate of a liquid inside the tube. The meter tubes cost little and require little maintenance. The tubes are replaced annually. They “give sufficient accuracy to make it possible to use them as a basis for charging tenants for the amount of heat used per heating season,” wrote Norman Taylor. Taylor, a member of the IDHA Metering Committee, briefly discussed these and hot water type meters, based on data from *Space and District Heating* by R. M. E. Diamant and J. McGarry, published by ILLIFE Books in England.

From a consumer perspective, the importance of accurate metering is fundamental. Metering, of course, is a modest concern and minor problem, but it is a representative element in the district heating package, and one of the most conspicuous elements for the consumer.

Part of the challenge for the introduction of district heating in America on the scale needed is building confidence in the technology, the equipment, the reliability of service, the continuation of warming and cooling energy through winter blizzard and summer heat wave. For most citizens the success of district heating in the Blizzard of ’88 is somewhat remote.

The technical status of district heating today is one of the strongest arguments in favor of the technology. Financial and social questions are considerably more difficult to solve. For instance, the question of district heating’s impact on a city’s already strained economy inevitably arises. “Will it put me out of work?” is an instinctive question. “Will it cost me more?” is another.

“District heating over a large part of any city would cer-
tainly eliminate many local home heating fuel businesses,” wrote Karkheck, “but pipe network construction would produce a net increase in total employment, and operation and maintenance of district heating systems would create new skilled positions.” [2]

Robert C. Embry, U.S. Department of Housing and Urban Development, was still more reassuring on this count at a 1980 North Central States District Heating Conference. Embry argued that district heating developments could revitalize urban areas and create many jobs. When district heating systems are operating, they can supply energy economically to low-income people spending up to 40% of their incomes for energy. The environmental benefits of district heating can also be substantial. [8]

These are factors in connection with district heating that affect confidence and can help to build it.

“The durability of modern materials ensures that district heating would result in very stable heat costs. This is an important feature which must be emphasized in developing consumer confidence in the scheme,” wrote Karkheck, and concluded, “The point is clear that district heating can and must be seriously considered as an important element in the solutions to our problems of energy supply and demand.” [2] This conclusion derives from European district heating successes.

The European experience with district heating is available to American cities, developers, and potential users. European conditions are not repeated exactly in the United States, but lessons learned in Europe are clearly adaptable to American circumstances. Finding out what has happened with district heating in Europe is a natural and necessary step toward effective district heating systems in the United States.

REFERENCES


District Heating in Europe

Capital costs for district heating are higher than the corresponding capital costs for natural gas. But in a world with increasingly scarce energy resources, we have found that with the rise in energy costs, the investments will very quickly bring a return.

Using district heating as the primary source of space heating will provide a secure and flexible heating supply that helps stretch the world’s resources of natural gas and oil, is of service to the environment and can ensure the consumer an inexpensive and comfortable form of space and hot water heating.

Lennart Larson, Chairman
Danish District Heating Association

The most urgent part of many national energy conservation campaigns since 1973 is to use, wherever possible, the heat otherwise wasted from electricity generation stations, refuse incinerators, and industry, instead of burning fuels.

Ernest Haseler, Founder
Ernest Haseler, Founder
District Heating Association of the United Kingdom

ZURICH'S ENERGY TREASURE: GARBAGE

Go to the northeast section of Zurich, Switzerland and you will come on the Josefstrasse power plant, easy to identify by
the prominent chimney. The main product of this plant is 45 tons an hour of superheated steam at 420° C. The steam is used to generate power and to serve a multitude of district heating applications in Zurich. The plant supplies apartment houses, public buildings, and industries. The fuel used by the Josefstrasse is 320 tons a day of Zurich garbage.

The Swiss clearly know what time it is today in the field of energy. Recycling refuse is a way of life in Switzerland, and the country is an estimated 20 years ahead of the United States in applying this special brand of cogeneration and district heating technology.

The city has put garbage to work to produce heat since 1904. The new system, started in 1978, is one of the world’s finest. Environmentalists who dread the pollution consequences of turning garbage into energy would take heart from Josefstrasse and other modern operations. Plant controls and the stack at Josefstrasse effectively protect the atmosphere, people, flora, and fauna of the Alpine nation. Yet even meticulous Zurich cannot prevent the mounds of unburnable ash that grow in the vicinity of incinerator plants. Some of this ash eventually is used to surface roads, and iron is also recovered as the recycling process continues.

Processing city sludge for fertilizer and methane is a recent development. Josefstrasse receives excess methane from the Werdholzli sewage treatment plant and burns it to cogenerate more heat and electricity.

Max Baltensperger, head of Zurich’s Department of Sanitation, spoke about the cogeneration benefits of his country’s refuse: “Garbage is today the ultimate material to replace oil, coal or gas. Four tons equal one ton of oil, and from this one ton of garbage we get three tons of steam. Garbage has grown from 16,859 tons in 1905 to more than 240,000 tons. Consider that in fuel-saving terms.” [1]

In the light of Zurich success with municipal refuse—reflecting comparable developments across Europe—the United States may be richer in vast energy reserves than many have believed. Per capita production of solid wastes in the United States grew
from 2.75 pounds per day in 1920 to more than 6 pounds per day in the 1970s. New York City generates 25,000 tons of garbage per day. A physicist at Dickinson College, Dr. Priscilla Laws, calculated that almost 1 percent of U.S. energy is consumed in the production of throwaways. “America is choking in its own solid waste,” said Laws. “Our response to this problem is depressing but not surprising. Instead of turning off the faucet we choose to mop up the floor.” [2]

Europe is both turning off the faucet and mopping up the floor by delivering wastes daily for incineration to produce heat that warms European homes, offices, and factories and to produce electricity that keeps the lights burning without added dependence on expensive conventional fuels.

The Zurich Josefstrasse operation is impressive but not exceptional in Europe. In a sense the operation exemplifies an established trend. An alternative fuel is used to relieve pressure on the scarce fossils, oil and gas. Cogeneration is used to avoid the characteristic inefficiencies of electricity-only power plants.

WHY EUROPE TURNED TO DISTRICT HEATING

Ileri, Reistad, and Schmisser wrote,

The conservation and wise use of all energy resources is an important national consideration. An available energy analysis of the energy consumption in the U.S. indicates that the overall energy conversion and utilization technology operates with greater than 75 percent wasting of the available energy used. In addition, it is revealed that a large part of this waste results from the use of high-level energy for jobs with low-level requirements such as space heating and domestic water heating. On the other hand, the large steam-electric power plants which have relatively good thermodynamic performance discharge tremendous quantities of low-level energy quite often at the detriment of ecology. From the ecological and energy conservation viewpoints, it appears necessary to combine these systems. [3]
The needs implied in this report have substantially been answered with cogeneration district heating operations in Europe. Many European cities are now upgrading these operations for combustion of refuse and other steps that should reduce the international problem of consuming high-level energy for low-level jobs.

Many European countries took advantage of their opportunity to move in the direction of energy conservation after World War II. Ravaged by war, the continent required massive rebuilding programs. Country after country, largely with direct government leadership, adopted district heating systems as the best available way to meet energy needs.

District heating allowed fuels to be used with optimum efficiency, and environmental improvements were also realized with district heating. Following Europe's example, Canada and Japan in recent years have increasingly favored district heating developments. Today the United States has an opportunity to benefit from European experience in the design, installation, financing, utilization, and successful marketing of district heating services. As noted, U.S. conditions overall do not duplicate European conditions, and the European experience is not automatically exportable everywhere in the U.S. However, many American cities parallel the climatic, size, and energy-need patterns encountered in corresponding European cities that have constructed successful, durable district heating operations.

American energy officials have toured European district heating sites. European experts have conducted seminars and workshops on district heating technology repeatedly in the United States. A formal governmental relationship among countries has not been formed on district heating, but exchanges of information, research findings, and equipment are common among European countries and with the United States to the extent requested. The International District Heating Association lives up to its name by providing a worldwide forum on the subject.

It is certain that technical advances achieved in Europe will promptly be known in the United States, and vice versa. It is equally certain that the developing U.S. district heating indus-
try will follow up any leads from overseas that help improve, expedite, or establish functioning district heating services.

The 20th century more than any preceding century primarily because of technological developments has allowed people in every country to enjoy access to technical and material advancements. At the same time the century has tended to turn many regional or continental problems into global problems. This is overwhelmingly true in the case of energy. The responsibility of energy conservation is clearly global in nature, and the practical solutions that help moderate energy difficulties become properties of mankind and global choices.

The United States launched modern district heating in the 19th century. Europe after World War II refined and enlarged it for modern needs. Now district heating, accomplished especially through cogeneration with electricity, is an international opportunity and a worldwide option.

Europe turned to district heating for obvious reasons: to meet energy needs, to cope with high energy costs (the surge of prices Americans began experiencing in the 1970s occurred much earlier in Europe), to conserve fuel and derive maximum benefit from fuel used, to safeguard the environment and achieve cleaner air.

The evidence was strong that district heating and cogeneration offered the most economical methods available to achieve such goals in part. That is why this traditional technology, stamped made in America, was adopted, absorbed, and Europeanized until the original American label was all but forgotten, especially by Americans, who now ironically often think of district heating as something developed overseas. Practically this is true, though historically it is inaccurate.

When European countries adopted cogeneration technology and constructed district heating networks, European cities had the urban densities required for economically viable district heating operations. Government and public support helped achieve the high participation levels necessary if district heating systems work.

The result is that in the 1980s, Europe has a well-established
district heating record. Old district heating systems are expanded and new ones built as a reaction to dependence on imported oil as well as proof of a broadly supported European commitment to maintain comfortable cities without allowing environmental deterioration. Millions of Europeans now receive heating and cooling energy and electricity with a convenience and confidence residents of many American cities would envy. Comparing energy consumption and waste, energy costs, and energy uncertainties that have harassed American cities during the past decade with the district heating facilities and services in Europe objectively, seems to provide strong arguments in favor of the European choice. Perhaps this confirms why so many American energy people have gone to Europe, studied the systems there, and returned home as missionaries for district heating technology.

EUROPEAN MATERIALS AND METHODS

European systems typically distribute heat by circulating hot water through insulated steel pipes. There are important exceptions, Josefstrasse in Zurich for instance which produces and delivers steam as in American cities. The use of metal pipes is a continuing, widely recognized drawback economically in district heating technology. The pipes are too costly both to manufacture and install.

Research to develop functional, low-cost, plastic or non-metal piping as replacements for steel pipes is intense and long-enduring. Closely related research efforts concern simpler, less obtrusive ways of installing district heating pipes.

Currently city streets must be torn up, traffic interrupted, and a general confusion fostered to put in district heating lines. The beneficiaries of the lines generally accept the intrusion and the upheaval because the construction clamor eventually subsides and they have permanent, reliable heating service available. Nevertheless, an obvious goal among district heating developers is finding ways to minimize installation efforts and difficul-
ties, which also naturally minimizes the stiff installation costs now suffered.

Western European systems commonly employ closed circulation systems involving two-way piping arrangements for circulation and return of the heating medium. This circular cycle achieves the highest degree of energy efficiency possible for large metropolitan areas.

District heating is equally popular in Eastern Europe. Some systems in that area are non-return systems, similar to the American arrangements. The non-return systems may achieve basically simpler operations, but they are less energy efficient.

District heating as a cogeneration product of nuclear power plants is vigorously supported by many Europeans as a future choice calling for current promotion and construction efforts.

WASTE YES, WANT NOT

The proverbial advice to waste not, want not has to be revised for contemporary energy application. Saying yes to the development of facilities for combustion of urban waste is proving an effective method of reducing energy want. Zurich's Josefstrasse plant is just one among some 200 plants in Western Europe that burn urban waste to generate heat and frequently electricity.

- Munich, Germany obtains about 12% of its electricity as well as district heating from incinerating garbage.
- In Paris, refuse is collected and processed for district heating and electricity.
- Nottingham, England uses refuse and local coal to district heat the central city.
- Amsterdam, Dusseldorf, Frankfurt, Vienna are among the many European cities with programs to derive cogeneration fuel from refuse.

Eventually most cities in Western Europe are expected to establish systems for recapturing energy from garbage. The ra-
tionality of the effort is indisputable: Refuse recycling for energy output helps solve both the problem of waste disposal and the equally serious challenge of supplying energy. Resource recovery and district heating in these cities are natural and inevitable allies.

Converting municipal waste and sewage sludge into important energy suppliers—electricity as well as heat—is acknowledged increasingly in the United States also as a significant wave of the future. Recovering resources, both acquiring energy and saving it (through reduced use of scarce fuels), and doing something with garbage besides pay for its burial or having it hauled out to help pollute the sea are realistic concerns of practically every American and European city.

"Refuse incineration could be a source of waste heat as well as a solution to urban waste problems," wrote Karkheck et al. "The garbage produced within a city of average U.S. climate could supply enough heat to meet the full needs of about 7 percent of the city's population. These alternative sources could be used to meet peak demands as well as contribute to the baseload heat supply." [4]

U.S. estimates are that extracting the heat energy from solid wastes could achieve 5–10 percent reduction in the use of fossil fuels. However, incineration and pyrolysis techniques, successful in Europe, before the present decade, received only limited adoption in the U.S., though future planning frequently includes such provisions as the 1980s move ahead. [5]

EUROPEAN SYSTEMS: VARIATIONS ON A THEME

In 1954 the Union of European Heat Distributors (UNI-CHAL) was organized to promote district heating. In 1970, under the auspices of UNESCO, the International Building Council (Le Council Internationale du Batiment [CIB]) was founded and began international development of district heating, gaining support from 54 nations.

The success of these groups, European in background and
motivation, attests to the postwar success story of district heating. In fact, it is difficult if not impossible to think of a comparable energy success story since World War II. Nuclear power plants were heralded in the 1950s as the answer to mankind’s quest for cheap and permanent energy; but this expectation turned into a pipedream and some would say into a nightmare. Nuclear prospects are still prospects, and a little the worse for wear after the public relations disaster of Three Mile Island.

District heating, however, as practiced in Europe has been a genuine winner. This energy success story embraces a number of countries, and the dimensions of the success are dramatically spotlighted by the fact that most of these countries say about district heating what Oliver Twist said about porridge, “Please, sir, I want some more.”

Scandinavia and Northern Europe have led in district heating development because their geographic location and climate made the technology particularly attractive and timely. But other European nations have followed suit with comparable systems either operating, under development, or planned. Using waste heat from generation of electricity, extracting thermal energy from urban refuse, and in general taking full advantage of cogeneration and district heating fuel-financial economies have become ubiquitous European phenomena offering a useful energy lesson to the attentive.

Consider these representative activities in various countries:

WESTERN EUROPEAN DISTRICT HEATING

Denmark

District heating has been important in this Scandinavian country for half a century, with accelerated development since the 1950s. In 1963 approximately 16 percent of Danish households used district heating service. By the 1970s, one-third of the houses in Denmark relied on district heating. [6] This percentage continues to climb as district heating becomes the dominant home heating method.
COGENERATION AND DISTRICT HEATING

The problem of enrollment is solved in Denmark through customer agreements to purchase heat at least 20 years. This is the usual repayment period for the loan given district heating users to finance initial changeover and connection charges. Membership in the system is not compulsory. However, the competitiveness of district heating keeps participation advantageous and makes it easy to recruit and retain participants. The principal heating medium is hot water at 100°C, although in 1976, the largest city Copenhagen used steam, according to Mikkelsen. [6] Most Danish district heating plants are fired by heavy fuel oil, while some use butane gas. Coal and uranium also fuel district heating operations.

Fifty percent of Denmark’s energy consumption is for space heating, predominantly supplied by district heating. Processing waste to extract useful energy is a growing Denmark practice. “Heat production at some of the district heating plants is supplemented with heat from refuse incineration,” wrote Mikkelsen. “Modern incinerator plants have been built in 25 Danish cities, and many of these are equipped with a heat exchanger coupling them to the local district heating system.” [6]

Approximately 60% of the country’s waste is used for district heating to supply 5% of the country’s total heating needs. In Copenhagen, the refuse generated by half a million people provides sufficient thermal energy to heat about 200,000 homes. Establishing combined heat and power plants for cogeneration efficiency is an objective for all the major cities in Denmark. Mikkelsen notes that district heating’s importance is manifest throughout the energy policy of Denmark “because it is both economical and beneficial to the environment.” Physically the Denmark systems show many features worthy of study. Concrete ducts, cast on location or pre-fabricated, are common. They require external and internal drains. Previously cellular concrete was the insulation material, but mineral wool or other materials fitted around pipes came into general use during the past 20 years. Asphalt-based insulation gives better corrosion protection for steel pipes in moist areas.
Prefabricated pipe products consisting of steel pipes, insulating foams, and plastic jackets prove economical in diameters up to 200 mm, with concrete ducts more economical for larger installations.

German Flexwell pipe made from corrugated copper and capable of absorbing thermal expansion has utilitarian features. Polyurethane foam is the insulation material. The pipe and insulation are surrounded by a steel tube and a plastic outer jacket. According to Mikkelsen, this Flexwell product was available as cable up to 350 meters in length and “is particularly suited to areas where there is little room for excavation, and to the installation of branches.”

Connection systems in Denmark have deviated from the norm in other countries of using indirect connections with heat exchangers at apartment dwellings or substations. This practice eliminates the danger of radiators bursting because of excessively high pressure from district heating mains. Indirect connection also adds considerably to costs and the difficulties of installation. Thus, direct connection became extensively used in Denmark. Denmark has established through studies on half a million consumer installations that “a radiator burst with serious water damage in a directly connected system is a very rare event.” [6]

A pressure differential control system with radiator return thermostats has largely replaced the earlier “mixing system” in which district heating water was added to the internal circulation water of the radiator system and regulated with manual or thermostatic controls. The new system is more energy-efficient because it is a once-through arrangement and no mixing occurs. Approximately 10 percent less water is required from the district heating system.

Nationwide district heating is the intent in Denmark. As district heating systems extend their coverage, oil imports are reduced, the environment suffers less pollution, and the consumer’s expense for district heating service goes down as well. District heating cogeneration with nuclear power plants is a potential future development in Denmark.
A fine line is still walked in Denmark with regard to compulsory district heating participation for greater efficiency and economy and with regard to democratic freedom. "In a democratic society it would hardly be right for a government to dictate use of a particular form of heating; nor indeed would it be possible. On the other hand, it is the politicians' responsibility to advance the form of heating most favoured with regard to resources, economy and environment," wrote Mikkelsen.

The answer in Denmark apparently is the classic one of making district heating service a distinctly reliable, convenient, and economical choice.

Finland

District heating began on a major scale in Finland during the 1950s. Growth was rapid. In 1960 there were six district heating installations. By 1976 there were 50 systems in 43 locations. Helsinki, with a population of half a million, meets about 65% of its heating requirements with district heating. The 1990 goal for Helsinki is expanding district heating to serve 85% of the population. [7]

In the beginning, the primary purpose was to salvage heat, otherwise wasted, from the city's thermal plants for hot water district heating. "Combined production of heat and back-pressure electricity began in 1960, and the downtown network grew rapidly," said Gunnar Smeds, Deputy Mayor of Helsinki.

In 1976 Helsinki had the following operating thermal facilities:

- 4 heat and power supply stations performing cogeneration
- 4 stationary heating plants for peak-load service
- 36 transportable heating plants

By using auxiliary coolers and heat accumulators, the full electric output capacity of the power stations is available during periods of a small heat load.
The commitment in Finland, according to Smeds, is to construct a cogeneration plant supplying combined heat and power wherever there is sufficient demand for the heat. Transferring heat from steam as it leaves the turbine to water for district heating by using a heat exchanger allows impressive fuel savings. “In a condensing power station, which generates electricity only, this heat is transferred to the condenser cooling water, where the heat is then lost in a river, in the sea, or in a cooling tower,” noted Smeds.

The Helsinki systems are designed for cogeneration plants to supply up to 60% of the annual heat load with hot water boilers coming on line to meet the heavier demands for heat during brief winter periods. These boosters can be located in the power station, connected in series with the district heating heat exchangers. They can also be located in scattered city neighborhoods to deliver heat in parallel with heat from the power station.

“District heating usually starts with a hot water plant. Steam boilers and district heating turbines are added later, when the heat load grows big enough. New and scattered suburbs are heated by mobile plants until it is feasible to join them to the main network,” according to Smeds.

District heating feed and return pipelines in Helsinki are nearly 250 miles long with regular additions part of the growth program. The pipes run in parallel and are identical in size for delivery of hot water and returning cooler water. Hot water pumped from a district heating plant is 75–120° C. Return water is 50–70° C. Going and returning water temperatures vary depending on outdoor temperatures.

Pipelines are generally laid at curbside, 2-feet underground, in prefabricated concrete ducts insulated with mineral wool. Careful installation and the equipment used keep heat losses as low as 4%.

Users are connected through a metering panel attached to each bulk consumer unit. Every consumer buys necessary heat exchangers and related equipment in a ready-to-install central heating distribution package.
Fuel savings began with the 20% savings resulting from producing heat in large plants rather than burning fuel in single consumer furnaces. There are substantial fuel savings as well from cogeneration.

Helsinki reports the following energy balance relationship:

<table>
<thead>
<tr>
<th></th>
<th>Condensing Power</th>
<th>Combined Heat and Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy in fuel</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Boiler losses</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>In-plant consumption</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Power yield</td>
<td>38%</td>
<td>27%</td>
</tr>
<tr>
<td>Condensing losses</td>
<td>47%</td>
<td>—</td>
</tr>
<tr>
<td>Thermal yield to district heating system</td>
<td>—</td>
<td>58%</td>
</tr>
</tbody>
</table>

The resulting efficiency ratio for condensing power production is 38% versus an efficiency for cogeneration of 85%.

These figures, corresponding closely with cogeneration efficiency calculations in the United States, clearly dramatize what is the overall best energy buy and what derives maximum energy from a barrel of fuel oil or a ton of coal.

In Helsinki, district heating allows the municipality to produce electricity at a competitive cost, while effectively governing consumption of heavy fuel oil. In 1977 Deputy Mayor Smeds reported a strange fact that must make U.S. mayors and city managers often develop telltale gleams in their eyes: “The energy business of Helsinki shows a profit, thus easing the pressure on the amount of the Municipal Tax.”

A tariff system attractive to consumers is the basis of district heating financing. The consumer pays an initial connection charge, with costs based on the contracted flow and his previous heating plant. The connection charges are designed to finance house hookups and also to help finance construction of the district heating network. Heat purchases are charged for
according to a double tariff, including a fixed annual fee based on a contracted maximum flow and periodical charges based on heat actually consumed. This arrangement complies with recommendations from the Finnish Heating Plants Association. Association requirements for district heating tariffs in 1976 were as follows:

1. District heating should be competitive with alternative forms of heating available to customers.
2. The tariff should be such as to promote the cooling of district heating water.
3. District heating undertakings should be able to balance their economy even under abnormal conditions, such as unusually mild or cold winters, or periods of heat rationing.
4. The tariff should be simple.

The simple tariff arrangement facilitates nationwide marketing of district heating. The convenience and competitive costs are also eloquent persuaders. Public meetings are held to supply information and answer questions when the district heating network is extended to a new area. New consumers generally volunteer, said Smeds, but he acknowledged one form of municipal pressure: “In some cases, the land-owning municipality has stipulated that new buildings be joined to the district heating network before consenting to hand the lots over to builders.” If this has the echo of coercion, in practice it is anything but. Most builders are happy to participate, in part because district heating hookups for new buildings may be cheaper than conventional heating plants and in part because district heating is good for Finland.

Among the “goods” other than fuel savings, cost savings, convenience, and reliability, a conspicuous “good” readily evident in Helsinki is greatly reduced smoke pollution and resultant cleaner air. Compared with individual home heating systems, district heating systems are benign friends of the environment. District heating consumes less fuel, which correspondingly re-
duces flue gases. District heating plants can be and are subjected to far more rigorous regulations and controls than could ever be successfully applied to individual homes within the confines of a large city, much less an entire country (or in America, a State). Flue gases at district heating plants are cleaned by electrostatic filters which achieve a separation efficiency of 99% in the newest installations.

Tall flue gas stacks, 300–400 feet, distribute all discharges in a diluted form over a much wider area than was possible with shorter stacks. Chimneys on Helsinki buildings have been progressively replaced by a few tall stacks. The result of the total district heating effort has been decreased SO₂ in the atmosphere despite increased use of coal and heavy oil with high sulfur contents. Finland is proving that district heating means cleaner air even with dirtier fuels.

“Combined heat and power production is also reducing the heat pollution problems related to energy production,” said Smeds. “The number of cooling towers can be greatly decreased by using the heat load of a community for production of back-pressure electricity.” Smeds also emphasized the reduced risk of land and sea accidents during the transport of oil and the reduced risk of damage from deterioration of oil tanks.

Distribution of electricity in Finland traditionally has been a municipal responsibility. This has extended to district heating as a result of cogeneration. Private power companies may join municipalities in joint ventures where local conditions encourage such an arrangement. Private industries in Finland with their own cogeneration capacity are encouraged and assisted to make surplus heat or electricity available to the community. Municipal, governmental, and private interests are considered objectively to achieve the best results for the national economy. Everyone can make a profit, Smeds contended, by careful tariff setting.

The Energy Policy Council of Finland in the 1970s recommended that “combined electricity and heat production should be adopted by industry and public utilities alike, wherever this
is technically and economically feasible.” This should be done when selecting modes of heating, although “preference should be given to whatever mode is most advantageous to the total economy.”

“Where residential density suffices, district or housing-group heating should take priority,” stated the Council.

Taking this advice apparently is a national habit. During the years 1975–1985, it was estimated that one-third of all public investments in energy would involve cogeneration plants, heat-alone stations for peaking needs, and district heating networks.

**Great Britain**

Britain was slower than some other European countries to launch district heating development on a major scale, but things began picking up in the 1970s. District heating was not a new phenomenon in Britain. As early as 1941, the Ministry of Works included district heating on its agenda of postwar concerns to investigate.

Among British developments is the hot water district heating system based on cogeneration involving 16 power stations in the heavily populated Liverpool area of Lancashire. The system’s development was promoted by the Central Electricity Generating Board.

In 1974, the Rothschild Study supplied a design basis for district heating in Great Britain. The design approach included provisions for a hot water system and warm air heating.

In 1976, A. E. Haseler at the third International District Heating Conference in Warsaw, Poland, reported that in England and Wales centralizing the heat supply and introducing district heating would mean fuel savings of 20–30 percent, and cogenerating heat and electricity would mean savings of 25–40 percent. [5]

District heating is still to be developed on a large scale in Britain, but the commitment is there as well as the recognized need.
Sweden

The State Power Board in Sweden establishes national fuel policy and gives the use of district heating to conserve energy strong national emphasis. The Board stresses a policy favoring cogeneration as the preferred mode for generating electricity. As a result of national energy and fuel policy, Sweden has developed elaborate and extensive district heating programs. Using waste heat from cogeneration power plants, potentially from nuclear plants, and from cooperating Swedish industry is nationwide and steadily expanding. The country's approximately 50 district heating systems are owned by the communities in which they are located.

District heating in the 1970s reached the point in Stockholm of supplying thermal energy to about half of the city's 700,000 inhabitants. When the 21st century arrives, the intention is to have 90% of Stockholm citizens and properties served by district heating for the large-scale energy and money savings as well as environmental dividends such an arrangement makes possible. District heating has already improved air quality in Sweden.

Trash-fueled district heating is among current and future Swedish district heating priorities. Plans have also been formulated to obtain heat from nuclear facilities built to serve Stockholm and other Swedish cities.

The U.S. Department of Energy in a report on cogeneration identified the cogeneration installation at Vasteras, Sweden as one of the largest and most successful in the world. [8]

The 900-year old city developed its district heating system in the 1950s to offset growing demands for costly oil and coal. A municipally owned system was operational by 1954 with heat from the Swedish State Power Board's thermal station in Vasteras and the city's oil-fired water boilers. New buildings in Vasteras had to be connected to the district heating system.

The city built its first cogeneration plant in 1961 because of
the growing need for more heating capacity and broader service. By 1963 the plant was supplying 47 megawatts of electricity and 95 megawatts of thermal energy. Further additions were later added to the plant. These were financed jointly by the city and four private power companies. The additions expanded electrical output to 230 MW and thermal output to 365 MW. By 1978 the cogeneration plant supplied 98 percent of the city’s heating requirements, as well as all the city’s electrical needs with surplus electricity delivered to the utility grid.

The Vasteras system shows what is possible with district heating and cogeneration. In less than a quarter of a century, the city established a system that meets virtually all of its energy requirements with substantial savings and environmental benefits as continuing extras.

C. E. Lind, National Board of Industry, Stockholm, described Swedish district heating as a process of heating water to 165–250° F in large, central plants and distributing it through pipes to buildings where heat exchangers process the thermal medium for room heating and domestic hot water. Improving air quality was a strong motive behind Swedish district heating development, and the effort has paid off significantly. Figure 7-1 shows air quality improvements resulting from district heating. [9]

Centralized production of hot water, according to Lind, allows the following:

- more efficient supervision of discharges through better air-cleaning equipment and higher chimneys to dilute flue gases.
- more thorough supervision of heating operations.
- using waste heat from industries instead of discharging it as thermal pollution.
- reducing the need for truck transport of fuels through city streets.

Following the oil crisis of 1973–1974, government support of
district heating intensified in Sweden. All communities are now required to consider energy factors in their planning activities. Stress especially is placed on using waste heat and applying any further reasonable measures to conserve energy. The National Board of Industry is authorized to award grants for energy saving projects, including district heating; and loan programs are in effect to assist development. Long before central government support began, local communities (e.g., Vasteras) acted to build district heating systems, promote cogeneration, and reap the benefits.

In a report on technical experience acquired through Swedish district heating development and operation, Erik Wahlman found a wide gap in efficiency between old and modern plants. He reported old hot water or steam boiler plants 50–60 per-
cent efficient, middle-sized plants 60–75 percent, and advanced modern plants 92 percent.

Swedish systems include all three because district heating has started in new areas as well as through retrofit efforts in central city areas. Swedish authorities warn that district heating benefits accrue gradually with each system. “It is necessary to build up the district heating system step by step from many small block heating systems” leading eventually to “a big cogenerating plant which delivers heat to the whole municipality and electricity to the grid.” [10]

Wahlman reports that average heat losses in modern big hot water mains are 5 percent. Smaller hot water mains in low density areas lose 10–20 percent of available heat. Such losses are minuscule in comparison with some of the older steam distribution systems without condensate return found in America and elsewhere. These operations can lose up to 70% of their heat. Steam distribution systems in good condition with condensate return have about 8% heat loss; without condensate return the heat loss is 20–30 percent.

Swedish experience testifies chiefly to the twin advantages of hot water district heating over steam and the wisdom of making certain new buildings start with district heating. Efficiency is less and changeover costs are much greater when older buildings and heating systems must be adapted to district heating. Yet even the costlier adaptations in the long run are a rational choice because they too pay for themselves as fuel prices continue to defy gravity by sliding up the curve.

Erik Wahlman supplied U.S. communities with excellent guidance when he wrote, “In the beginning the district heat utility will have a substantial investment in the mains and hot water boilers and will also have high operating costs. The investments must be time-scheduled according to the prognosis of connected customers so that as large a load in the mains as possible can be reached. That’s why it is essential to build up district heating step by step.” [10]

Substantially that is what was done successfully in Sweden.
EASTERN EUROPEAN DISTRICT HEATING

Bulgaria

The national capital, Sofia, 310 miles northwest of Istanbul, is one of Europe’s ancient cities. A district heating system is now used to supply heat in Sofia and to serve the city’s important commercial activities.

Czechoslovakia

Cogeneration heat and power from nuclear plants designed with pressurized-water reactors are planned in this eastern country where state ownership of heat and power plants makes district heating both a political and a technical decision. The same is true, of course, in the United States without state ownership, because of federal-state-community regulatory mechanisms and because of the desire if not the indispensable need for public financing.

German Democratic Republic

The decade 1964-1974 produced an increase of 132% in the heating capacity of district heating systems. The goal by the 1980s was to have 90 percent of new homes (415,000) equipped with district heating service.

Hungary

In 1960, hot water heating for new housing developments was the initiating goal of the Budapest Municipal District Heating Works. By 1965, 23,000 homes were connected. The number increased to 104,000 by 1975.
Poland

Thirty Polish communities were served by cogeneration district heating in the 1970s. Ten more towns received surplus heat from condensing power plants. Nearly all Polish towns have local plants that supply heating service, though not in the cogeneration mode. More than 100 Polish industrial power plants deliver heat to adjoining housing developments. In 1975 heating and hot water production had a 21% share of the generating capacity at commercial and industrial power plants in Poland. The percentage by 1990 is expected to be 58.4% if planned energy goals are reached.

Romania

In 1969, units used for district heating supplied only 11.1 percent of annual heat generation, although the units represented 30% of total capacity. Responsible for the disparity was the seasonal nature of space heat requirements in Romania compared with consistent annual requirements for process steam. In 1970, approximately 25% of installed capacity was in back-pressure units operated at 1005° F, 1470 psi. Calculations in 1970 showed energy savings with district heating of $6.9 \times 10^{13}$ Btu and expense savings at 15–22 percent of total cost depending on central plant size.

Soviet Union

In 1979 Barbara Ward wrote, “A large portion of the Soviet Union’s rapidly expanding electricity capacity comes from power stations whose waste heat is used for district heating.” [11] This identifies the heart of Russia’s massive district heating thrust. With the world’s leading volume of cogeneration energy production, Russia has more than 1000 stations supply-
ing heat and electricity to about 800 cities. Domestic heat demand in 1970 was 50 percent met by cogeneration. Now in the early 1980s nearly 70% of Russia’s heating requirement is filled from cogeneration and district heating supply sources. The pattern of district heating growth characteristic of other countries in Europe is also prevalent in the Soviet Union. [12]

**Yugoslavia**

District heating practices in Yugoslavia copy some of those familiar in other parts of Europe. Yugoslavia has also introduced a new variation. At Kikinda in Yugoslavia, the district heating project includes using heat pumps on geothermal waters.

This reflects a notable feature of district heating. District heating can be used with any fuel or heat source that can deliver thermal energy or from which thermal energy can be extracted (oil, gas, coal, nuclear, solar, geothermal, wood chips, municipal refuse, what have you). [12]

**DISTRICT HEATING PROGNOSIS IN EUROPE**

The district heating course in Europe takes all available directions, and all directions are up. The trend is stated with one word: growth. The tendency is expansion. The prognosis for the patient harassed by energy shortages and energy bills is good progress in attacking both symptoms.

Henrik Harboe, in *Energy*, noted the inefficiencies of oil/gas/electric home heating and wrote, “District heating can greatly improve these inefficiencies.” [13] The statement or idea is one worthy of preserving on cornerstones in Europe where most countries have found that fuel efficiency is a national necessity whatever medicine must be taken to achieve it. District heating often turns out to be, not a medicine at all, but a stimulating energy shot in the arm.

European district heating developments at the start of the 1980s included:
Austria, Denmark, the Netherlands, and Norway authorize low-interest loans to industries for investments in energy-saving equipment and cogeneration efficiency.

New European housing is typically added to existing district heating networks.

Great Britain encourages district heating with grants to cooperating businesses.

West Germany, served by nearly 474 central heating networks, has a tax allowance for cogeneration development and now gets close to a third of its electricity from cogeneration.

Harboe wrote, "Only governments, whether they be city governments or national governments can assemble and execute the financing programmes required for large district heating schemes. The timescales are too long and the benefits too indirect—for they are in many respects reaped only indirectly by the individual and directly by the nation—for schemes such as district heating to be corporately or privately financed." [13]

This statement raises important, highly debatable issues. The jury is out and hasn't yet returned with a final verdict on whether or not private industry can beneficially develop district heating in the United States while taking advantage of cogeneration opportunities. The projected arrangement in the 1980s between Dow Chemical Company and Consumers Power Company is evidence that industry when it is big enough can undertake projects normally left to governments.

In Europe the relevance of Harboe's argument need arouse no controversies since European governments have taken the lead during the past quarter century in finding ways to promote rapid, methodical development of nationwide district heating systems.

European district heating programs have posted convincing records of energy saved, urban environments improved, and energy costs realistically controlled for individual consumers. The results show that national and/or community planning, cooperation, and foresighted investment can create energy systems that pay off handsomely in the long-run. This progress has

...
been accomplished using well-known cogeneration techniques and the idea Birdstill Holly activated over a century ago in Lockport, New York. The same technology obviously is still available to help the United States again achieve some measure of energy self-sufficiency.

PERSPECTIVES ON DISTRICT HEATING IN EUROPE

These photographs help suggest the extent and significance of district heating technology in Europe.

Figure 7-2. (left) A protective sheath about district heating hot water pipes pays off in efficiency and energy saved. Foam insulation on distribution and return pipes is one reason district heating systems achieve optimum use of energy resources. Installing district heating pipes is complex and costly. City streets are disrupted while the lines go in. Residents try to take the interruptions with good humor, because they know the ultimate benefits. When the district heating system is in place, they are supplied with heat more economically and dependably than before. The few who complain about broken pavement share the satisfaction when district heating service starts. (right) Each new district heating development means reduced air pollution as the tall exhaust stack replaces individual chimneys. The stack distributes emissions over a broad area. European cities reported steady improvements in air quality when district heating was employed.
Figure 7-3. Schematic of a district heat pipeline in a concrete element construction with mineral wool insulation.

Figure 7-4. Investments in district heating technology pay dividends in energy savings and in capital savings too as conventional fuel prices rise.
Figure 7-5. District heating pipes can reach from a city source to serve outlying districts with thermal energy in the form of hot water or they can reach from a power plant beyond city limits to heat urban residences.

REFERENCES


Cogeneration and District Heating in America

A time of turbulence is a dangerous time, but its greatest danger is a temptation to deny reality. The new realities fit neither the assumptions of the Left nor those of the Right. They do not mesh at all with "what everybody knows." They differ even more from what everybody, regardless of political persuasion, still believes reality to be. "What is" differs totally from what both Right and Left believe "ought to be." The greatest and most dangerous turbulence today results from the collision between the delusions of the decisionmakers, whether in governments, in the top managements of business, or in union leadership, and the realities. But a time of turbulence is also one of great opportunity for those who can understand, accept, and exploit the new realities. It is above all a time of opportunity for leadership . . . for the decisionmaker in the individual enterprise to face up to reality and to resist the temptation of what "everybody knows," the temptation of the certainties of yesterday, which are about to become the deleterious superstitions of tomorrow.

Peter F. Drucker
Managing in Turbulent Times [1]
COMEBACK OF AN ENERGY OLDTIMER

District heating lost favor among utilities because they could earn greater profits concentrating on the production of electricity. District heating lost favor with the public because oil and gas were plentiful and low-priced, and individuals were sold on the challengeable idea that oil or gas heating are private and convenient like the family automobile. Each home should be self-reliant and independent with a furnace of its own. Of course, if it happened to be a gas furnace, the gas arrived by pipeline the same as hot water or steam in a district heating operation. If the furnace burned number 1 or number 2 home heating oil, the oil was discharged into the basement tank by means of a long hose from an oil delivery truck. Independence has been an illusion in home heating since chopping wood on your own North Forty ceased to be an American practice except for the rustic privileged few.

District heating is regaining favor—slowly—because the illusion of independence counts for little when the oil in your house costs nearly as much as the gasoline in your car, which costs more today than it cost yesterday, and it cost too much yesterday. The gas furnace with the small constant blue flame in the pilot light becomes a potential albatross when the newspaper warns about winter natural gas shortages or the bill arrives and you remember what you were paying the same time two years ago.

District heating couldn't be worse and might be better. This is the assumption fostered by the new realities of energy in the 1970s and the 1980s. But despite the fact that district heating and cogeneration to eliminate traditional utility waste have been around a long time, are becoming standard practice in other parts of the world, and are available to American communities for the taking, the number of takers remains small.

It is worthwhile to consider various district heating activities in communities, institutions, and industries that are making progress in the United States, frequently with thanks to the
foresight and farsightedness of a few individuals who have studied the history of district heating, or who learned about its potential in Europe, or who just pay attention to the fuel combusted annually in America and the amount of real energy benefit that is gained. The facts that U.S. energy consumption is overwhelmingly greater than that of any other country on earth and that U.S. energy waste equals the energy consumption of most countries on earth have been well-publicized. Doing something about the consumption and the waste has been labeled with the 12-letter dirty word "conservation."

District heating is basically an energy conservation technology. If and when district heating begins achieving its full potential in the United States, conservation may cease to be a dirty word to those Americans who consider it vaguely unconstitutional and decidedly unreasonable, uncomfortable, and unnecessary to turn down the thermostat. This old technology that time has rendered new again seems ideal as a way to make the pains and fangs of conservation considerably less difficult.

Following are representative district heating projects briefly discussed. Cataloguing all the district heating/cogeneration activities and projects current in the U.S., either off the drawing board or on it, would be encyclopedic in scope and is beyond the needs of this survey. The examples cited are intended to suggest the range of options involved in this technology and the versatility it allows.

District heating can be and probably in time will be used with virtually every conceivable energy source. The same is true of the cogeneration principle. If an energy source is capable of generating electricity, there is probably also the capacity to some degree of delivering thermal energy as well for district heating applications.

• Geothermal energy provides heat at Boise, Idaho and Klamath Falls, Oregon for district heating systems.
• Nashville, Tennessee saves customers as much as 50% on their energy costs for chilled water and steam service by incinerating solid waste.
Detroit Edison is studying waste incineration as a possible aid in revitalizing an elderly but still functioning big city district heating steam system.

Steam from a new nuclear plant at Midland, Michigan on the Tittabawassee River will supply process heat to one of America’s largest industries, Dow Chemical Company, with steam left over for community development.

Eastern Michigan University, Ypsilanti, Michigan is one of many institutions studying the economics of adding co-generation of electricity to its steam production system through upgrading and expansion.

CITY DISTRICT HEATING PROGRAMS

Bellingham, Washington

In a district heating arrangement involving an American city of 45,000 people, Bellingham, Washington, and an aluminum processing plant, Intalco, thermal energy that would otherwise be wasted will heat approximately 12,000 houses and the campus of Western Washington University.

After a long assessment and study period, the plan in 1981 was to install district heating service to 40 homes on a demonstration basis. Bellingham intended to finance the project in part through the sale of revenue bonds.

Mayor Kenneth Hertz of Bellingham spoke about the co-generation–district heating program and what it meant to his city:

Success will depend on citizen acceptance and support. We’re using every available medium to explain the project to the public and make all our people active participants in an ambitious community effort. Change of this sort is never neutral, and it is often tempting for the legislative body to avoid or defer decisions of this financial magnitude. The project is not killed, it is starved. By preparing citizens for the change and putting energy issues squarely on the
public agenda, Bellingham is seeing to it that district heating doesn’t starve here. This energy step is too important for the area to be stopped by fiscal timidity, the temporary nuisance of tearing up streets to lay pipes, the problems of a big bond issue, or any other delaying tactics. We can use heat now being wasted, which means district heating and energy responsibility are one and the same here.

An extensive community awareness and instruction program was carried out during the preliminary studies and every subsequent phase of this project to keep it a communitywide and communitywise undertaking.

Intalco has the largest aluminum processing plant in the world and is located about 15 miles north of Bellingham not far from the border of British Columbia, Canada. If economic feasibility studies prove that the cogeneration–district heating project will accomplish what its supporters expect, full-scale development should get underway before the end of the 1980s.

The plan is a classic example of industrial cogeneration, showing what is possible when a large manufacturing facility and a nearby community work to promote a mutually beneficial symbiotic relationship, with more efficient energy use as the end result.

Detroit, Michigan

The City of Detroit is cooperating with the local utility, Detroit Edison, to broaden the use of cogeneration and district heating in the city. A primary goal is to upgrade the existing steam district heating system in the central city. Another goal to be implemented in the course of extending district heating benefits to other Detroit neighborhoods is to construct a new refuse-fired cogeneration plant as a way to conserve fuel and cut costs. The district heating program, designed for both public and industrial needs, is a key building block in the city’s long-range energy plan.
Minnesota Community Projects

In a study sponsored by the Department of Energy, 39 steam turbine power plants in Minnesota were analyzed to identify those that could be retrofitted for cogeneration. Red Wing and Moorhead, Minnesota were found to have suitable facilities and available customers to support development of hot water district heating systems. The two cities hope to acquire financing and to keep their district heating hopes alive.

“The basic fact of life is that our community has relied too heavily upon electric energy for heat. We must find ways of shifting this demand on other energy sources,” reported Mayor Morris L. Lanning of Moorhead in 1980. [2] The Mayor thought district heating may be Moorhead’s best answer.

Newark, New Jersey

The objective in Newark is determining the feasibility of equipping fossil-fired steam generating plants to reduce energy waste by supplying district heat in surrounding communities. Among the cogeneration proposals is a large-scale project to outfit a decommissioned power plant to use refuse and sludge as primary energy sources. Newark and Jersey City are heavily populated areas with many potential customers for district heating service. Making energy use more efficient would aid the cause of saving energy. It could also have a helpful, restorative effect on the economy of a depressed urban area.

Philadelphia, Pennsylvania

The Philadelphia metropolitan area could increase fuel savings eightfold by developing the city’s cogeneration potential. A proposed system includes converting four fossil-fired power plants to transmit hot water for district heating. The 8-stage
construction program from 1985 through 2004 would cost an estimated $916,000,000. To handle this formidable expense, an ownership arrangement involving both the city and participating utilities was recommended.

Piqua, Ohio

The intention in Piqua, Ohio is to build a hot water district heating system that is supplied by the city's electric power plant via cogeneration. A Piqua City Commission accompanied by Mayor Sam Jackson toured European district heating facilities and studied cogeneration plants to get ideas and information that would be helpful back home. If the district heating plan is carried out, the system will stimulate economic development while stabilizing energy costs and making it easier for Piqua, a city of 23,000, to attract new industries and businesses. Mayor Sam Jackson noted the effort made by his predecessor in office as well as himself to keep the district heating program on the road and moving forward. "Energy projects outlast office holders," said Jackson. "We come and go, but energy projects go on because heating and cooling requirements are permanent."

The Piqua power plant that will be retrofitted for cogeneration is a municipally owned, coal-fired plant. The market in Piqua for thermal energy is estimated at 200 MW thermal. The initial system is planned to supply about 20,000 pounds per hour. Service will be in the downtown commercial area first and then will expand to most residential neighborhoods. [3]

The success of district heating here—in both energy and economic terms—could have national significance for many other small cities often dismissed as district heating prospects because they lack the dense metropolitan populations sometimes considered essential to make district heating competitive. Smaller communities in Europe succeed in establishing district heating systems that function efficiently. Piqua, Ohio might show that some of the assumptions made about district heating
as an energy technology for large cities are not altogether accurate. Smaller cities have people who need heat delivered to their houses; they sometimes have power plants that are wasting heat. These are the knowns that make the district heating equation work.

Pittsburgh, Pennsylvania

Local efforts to prevent functioning district heating operations from disappearing are sufficiently uncommon to be notable when they occur. Citizen groups readily form and march to City Hall to prevent the demolition of a historic ruin, but the same enthusiasm for a district heating service threatened by red ink entries in company ledgers is unlikely. Now Pittsburgh has made certain it is not unprecedented. Pittsburghers fought to keep their steam flowing.

Richard R. Kay, President of the Building Owners and Managers Association in Pittsburgh, wrote in 1980, “A group of users is trying to save the existing central steam heating system. . . . The future of central steam heating depends on continued user participation and, in this respect, things are looking up for the Allegheny County Steam Heating Co.” [4] Kay’s idea of “things looking up” centered on the fact that the utility had asked customers whether they wanted to stay with the system, and only 7 replies out of 122 were negative.

Trouble developed for the operation when it lost money (about $10-million) and the parent company considered dropping it. Then the community drive began. Engineers reported the system worth salvaging. Investment bankers and consultants reporting as a consortium said, “Our experience in evaluating the alternative costs of energy for heating and cooling in densely populated areas has shown that central systems are the lowest cost source of energy.”

Whether or not Pittsburghers would save their district heating system, at least the battle had been joined. A group of
citizens had spoken up for a needed service and tried to help find viable ways of making the venture sufficiently profitable to survive. This citizen commitment may be one of the most positive and potentially effective allies district heating can find. Pittsburgh offers active, crusading proof that users of district heating steam or hot water are not indifferent to the convenience of district heating and want to keep it operational.

St. Paul, Minnesota

The U.S. Department of Energy identified four main reasons the Minneapolis–St. Paul area is appropriate for district heating development. [5]

- Cold climate (8300 degree days)
- High population density
- State and community interest
- Location of existing power plants (fossil and nuclear)

To help St. Paul reach its district heating goals in the 1980s, a not-for-profit district heating development company was established. Cogeneration of hot water at an existing power plant for distribution in the downtown area is the first phase of the project. The fuel and cost savings of the operation could be extensive. Estimates are that heat will be supplied at about 50% the cost of oil and 75% the cost of natural gas. Using tax-exempt financing, the St. Paul project shows a significant net accumulated value over a 20-year period according to feasibility studies made by Oak Ridge National Laboratory. [7] A district heating assessment for the Minneapolis–St. Paul area showed energy savings of about 50 million barrels of oil equivalent during the first 20 years, and thereafter about 5 million barrels per year.

Starting with service in downtown St. Paul, the total system
will provide district heating savings to the metropolitan area of the Twin Cities, Minneapolis–St. Paul.

The St. Paul district heating program made progress because forceful support has been given by state and local officials including Mayor George Latimer who said, “Energy is too important for partisan politics. We knew we couldn’t wait for it to happen. We had to make it happen. In St. Paul we’d rather not wait. District heating is needed as soon as we can get it.”

The area traditionally has relied heavily on oil and gas. Savings on these scarce fuels are estimated as high as 86%, with net energy savings 54% over conventional systems when the system is operational. [6]

This district heating system is needed and wanted, but the entire Twin Cities system could take 20 years to build at a cost in 1980 dollars of $750-million. Completed, the system would supply 2,600 megawatts to the Twin Cities; but aggressive leadership will be required to find the necessary funds and keep momentum going. Latimer’s previous comment merits repetition, because it sounds like the main answer in American communities trying to do something constructive for the future with hard-to-assemble current investments: “I am of the definite opinion the people are tired to death of overcautious politicians.”

If hot water district heating cannot be made to work in St. Paul, its chances elsewhere in the United States would be more questionable. The area has the cold climate, concentrated populations, dependence on scarce fossils, and existing coal-fired plants considered optimum for successful district heating development and operation. When hot water flows through district heating pipes in St. Paul, the future of the technology in the United States will be improved. St. Paul today, tomorrow the continent. But if hot water district heating cannot be done in St. Paul, then where can it be done?

The determination expressed at the St. Paul District Heating Development Company allows no doubt that somehow mountains (of money) will be moved, pipes will be laid, and the hot water will flow.
THE TOTAL ENERGY PLANT

Institutions, housing developments, medical centers, shopping centers—all are potential candidates for cogeneration of both heat and electricity in their own power plants. Such candidates are found in virtually every part of America. Older establishments can be retrofitted to accommodate the special needs of cogeneration, though this is costlier than taking that direction in the planning stages of a new development. New developments certainly should consider carefully whether or not long-term economic benefits will be realized from going the Total Energy Plant route.

The Regency Square Shopping Center, Jacksonville, Florida, operates one of the nation’s largest private total energy plants. In 1981 the center was expanding from 630,000 to 1.1-million square feet and hooking up with Jacksonville Electric Authority, the local utility, to make cogeneration more efficient.

The shopping center late at night will receive electricity from the utility. During the day, the center will operate its own generating equipment and return power to the grid.

"Regency Square will be virtually a generating substation," said Robert C. Gillander, Jr., General Manager. "It is hoped that the give-and-take of power between Regency and JEA will result in a balance each month, with neither side 'owing' the other."

When the shopping center was built in the late 1960s, the owners compared the cost of installing complete power generation equipment with the cost of obtaining power from the utility, and self-generation was the best investment. Regency Square’s power generating package is summarized in Table 8-1. In addition to electricity, the plant will use exhaust heat to produce steam for heating. An absorption unit allows the plant to provide its own air conditioning.

The cost of available fuel and existing electric rates are factors that help developers decide if a total energy operation optimally meets their needs. With climbing fuel prices and
Figure 8-1. Generating power at a total energy plant. Six Worthington engines and seven Caterpillar engines provide cogeneration electricity and steam to the Regency Square Shopping Center, Jacksonville, Florida.
### Table 8-1. Regency Square Shopping Center
Power Generating Package

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<td>10,550 kw</td>
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<td>Seven Caterpillar Engines</td>
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Electric rates, the energy efficiency and savings of the total energy plant approach can make such plants good investments now, superb investments tomorrow—"tomorrow" meaning later in the 1980s and in the 1990s.

Robert C. Gillander informed the author, "Shopping center owners who consider Total Energy Plants should examine fuel costs, the largest operating expense in such a venture. Prevailing electric rates are another major factor. The higher they are, the better total power may look. The technical side is relatively easy. The hard part is working out the details of an agreement with the utility."

Regency Square Shopping Center has the agreement and the total energy plant. Cogeneration assures that less fuel is consumed than would be required without cogeneration. The energy system and associated energy program in Jacksonville involving the shopping center and the utility are potentially applicable many other places.
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Cogeneration and district heating activities involving American utilities generally, with specific reference to a few operations such as Consolidated Edison of New York and Indianapolis Power and Light, have been discussed.

Two widely separated utility situations provide interesting contrast and help illuminate both the history and scope of utility cogeneration and district heating in America. First let’s journey south and west to Southern California.

Applied Energy, Inc.

“Good Americans, when they die, go to Paris,” wrote Oliver Wendell Holmes. [8] Given a choice they would probably choose San Diego instead, better climate. Applied Energy, Inc. is a subsidiary of San Diego Gas and Electric Company with successful cogeneration in progress and growing since 1971. Navy or Marine Veterans who “shipped” from San Diego as the author did will recognize several of Applied Energy’s cogeneration customers.

The company operates four cogeneration plants that supply steam to the Naval Training Center, the Marine Corps Recruit Depot, San Diego Naval Station, and North Island Naval Air Station. Taxpayers will appreciate learning that since district heating services began here, the military bases pay less for the steam they use. Both customers and the suppliers have benefited, according to a Department of Energy report on the operation:

Prior to buying steam from Applied Energy, each military base produced its own steam using direct-fired boilers in separate, central boiler plants. Operation of the cogeneration plant has resulted in a net annual savings over the single-purpose heating facilities. In addition, the labor and maintenance costs incurred by the central facility to supply the needed steam are less per year than they were for the
single-purpose heating facilities. . . The military bases have realized a reduction in the cost of their steam energy; the utility has found a new source of revenue in its product steam; and the community has experienced less air pollution and been able to conserve fuel for future use." [9]

The parent company of Applied Energy has had experience in cogeneration for well over half a century. San Diego Gas and Electric began supplying downtown San Diego with steam in 1921. The present activities are a natural extension of long-established services.

When the program was initiated, over two miles of steam pipeline connected the first two military bases (The Naval Training Center and the Marine Corps Recruit Depot) with the cogeneration plant. Since 1971 the program expanded to include additional military bases and an industrial plant in Southern California.

Applied Energy has heat recovery boilers attached to turbines for topping cycle cogeneration. Electricity is generated and given to the utility grid. Steam goes through district heating pipes to the military and industrial users.

In 1979 Applied Energy began operating a cogeneration plant to supply the steam requirements of ROHR Industries, Chula Vista, California, again with electricity directed to the utility grid.

Applied Energy’s cogeneration undertakings in the area have saved energy and made the environment cleaner. Other military installations—and industries—near utilities with cogeneration capacity might beneficially ponder the San Diego experience. In a single decade major benefits were accomplished for energy users and energy suppliers by adapting cogeneration and district heating technology to a specific local situation and particular need.

**Detroit Edison Company**

Delivering steam to buildings in the heart of Detroit began in 1903 and has continued to the present. The company sold
steam in the early years of its history because it was the surest way to hold electric customers. “Where buildings and manufacturers were compelled to maintain furnace equipment and crews for heating, owners found they could economically provide power and light as well. Before they could become users of Company electricity they had to be given an alternative source of heat,” wrote R. C. Miller in his history of Detroit Edison. [10]

This page from the past may have relevance for the future. Organizations and institutions are again recognizing that if they operate equipment to generate heat, they may also be able economically to generate electricity. Supplying such customers with thermal energy may become a practical requirement for holding them as major electric customers.

The company records of Detroit Edison, wrote Miller “contain the story of the building of Detroit, told in alternating moods of pain and pleasure. With every new downtown building the Company faced the necessity of urging architect, engineer, and builder to use its service instead of using an isolated private system. Each new building presented its own complex of problems and conditions, involving light, heat and power.”

The same must be true of practically every modern city. All the clues to its past history will not be found in City Hall records or in yellowing newspapers. Networks of underground pipes and wires must also be consulted.

The current stimulus given cogeneration and district heating by potential fuel shortages and high prices is one more illustration that history repeats itself. Detroit Edison’s district heating operation didn’t really come into its own until World War I. “The advantages of central heating were never so emphasized as they were in the period of wartime fuel shortages and attendant erratic prices,” wrote Miller. We hear the past speaking to the present.

Heating service grew along with the city during the 1920s. A downtown building boom required increased capacity and district heating lines to new areas. The period was characterized locally by competing claims about where the world’s largest
steam boiler was located. Detroit Edison’s Delray plant and Conners Creek plant shared the title briefly with 23,650 square feet of heating surface. Then a boiler at the Ford plant in River Rouge became the champion, followed by the giant Beacon Street boiler measuring 42,370 square feet.

Boilers were large and service extensive, but difficulties long associated with district heating in America began to show. Production of eight pounds of steam from one pound of coal was the general rule, which larger volume production, greater efficiency, and plant improvements could do little to change for the better. “About 15 per cent of the heat of this steam was lost in transmission through the tunnels and pipes. Labor costs were not insignificant, but they were relatively small in the total,” wrote Miller.

Huge capital investments were necessary even then to build distribution networks, and a low annual load factor because of seasonal use meant serious reduction in sales volume.

“A dollar invested in the electrical system would produce a gross return of roughly 50 percent more than a dollar invested in the heating plant,” Miller reported. “Raising rates enough to balance this would have been impractical; only to some customers were the established rates actually economically justified and advantageous, and only to some could the Company offer the combined electric-heating services on a profitable total basis. The retirement of some small buildings, especially in the downtown area, actually reduced the number of customers; there were fewer accounts in 1950 than in 1920, though the steam output was vastly larger. The heating business did little more than pay its own way; it was maintained and even extended because of the profitable electrical load which was related to it.” [10]

The contemporary Detroit Edison district heating system has approximately 60 miles of underground mains, 2.5 miles of tunnels, and over 800 customers. The company and the City of Detroit are collaborating in the development of a plan and program to expand district heating in Detroit.

Company assessments indicate that a steam district heating
COGENERATION AND DISTRICT HEATING

system is preferable in Detroit to a hot water system, notwithstanding the technical advantages of hot water for district heating. The main reason is the continuing availability of large industrial customers for process steam.

A large-scale expansion of Detroit district heating might include hot water service as well as steam service. Constructing a refuse burning plant to extract energy from Detroit garbage is an important feature of local planning. Estimates are that refuse could meet approximately 50% of the fuel requirements for district heating in Detroit. The importance of this move is highlighted by the fact that the utility in recent years has used natural gas to supply steam customers. Substituting refuse, coal, or other alternate energy to replace gas and oil is a priority concern.

District cooling is another potential feature of the Detroit program. This feature and the others hinge on the ability of the company and the city to implement planning. A joint statement by Detroit Edison and the City of Detroit, January 30, 1980, emphasized that developing new equipment and technology is not required, but “the cost of installing the distribution system is the overriding component for the district heating system.”

Where’s-the-money-coming-from is the question again. Those impatient with delays and the perpetual concern about in-front financing are tempted to argue: Stop worrying about who’s going to pay and where the money’s coming from to do it . . . and start doing it. Alas, in the so-called real world, the “do it” ethic has become naive and the voice of one crying in the wilderness. The rules must be obeyed or nothing happens. All the regulatory t’s must be crossed and all the financial i’s must be dotted. At least to a point. Progress is still made because people make it happen. They keep pushing until they push on the right door and make it happen.

Detroit is both realistic and resolved. “It will be necessary to review design and installation philosophies very carefully, and to take advantage of some of the advancing piping systems now used in Europe,” said the joint statement early in 1980.
Walter McCarthy, President of Detroit Edison, is one of those identifying institutional and economic factors as the main obstacles to new or improved district heating developments based on utility cogeneration. He sees a successful future for district heating lying in the use of coal and refuse to produce steam rather than the use of costlier oil and gas.

The Pittsburgh experience in which steam service must fight for survival is not anticipated in Detroit. District heating service should still be active—and hopefully expanded as Detroit planners want—when the time arrives to commemorate the centennial of Detroit district heating in 2003.

INDUSTRIAL COGENERATION

The combined production of heat and electricity by industry has perhaps the greatest untapped energy conservation opportunity available in the United States. Some industries have not wanted to go into the power business, convinced they have enough headaches staying on top of their own business. But costs in the 1970s began making energy everybody’s business if he planned to stay in business. The result is that cogeneration is being evaluated and adopted by a growing number of industrialists.

Yergin described how the topping cycle is applied in some industrial situations:

Energy is used to produce combustion at temperatures up to 3600° F in order to get steam that need not be any hotter than 400° F. Obviously, a great deal of energy is wasted in the process. In cogeneration, the high temperature is used to make gas vapor or very high pressure steam, which drives a turbine or a rotating shaft, which in turn generates electricity. As in a power plant, the waste from this process is steam, except that in this case the steam is not waste, for it then goes on to be used for industrial processes. The energy is thus cascaded from uses that require high temperatures to those that require lower temperatures. This is called high-quality and low-quality energy uses. [11]
In the earlier part of the century, it was common for industries to cogenerate both electricity and steam. That was the situation Detroit Edison combatted by offering steam service as well as electrical service to Detroit industrial customers.

Gradually the practice of industrial cogeneration declined, partially because of complicated regulatory restrictions, mainly because the cost of electricity from utilities for industrial consumers was so low there was little incentive to pursue cogeneration savings. The trend away from industrial cogeneration continued well into the 1970s.

Approximately 15 percent of U.S. electricity was generated by industry in 1950. The quantity was down to 5% in 1973. In other countries a different situation is encountered. In West Germany, 27 percent of electricity is industrially produced, with half of this amount the output of cogeneration. In Great Britain, industry supplies 20 percent of its electrical requirements. Various analyses indicate more than 20 percent of U.S. industrial energy consumption would be saved by cogeneration. [11]

"Industry is sitting upon an easily recoverable, relatively cheap new source of energy," wrote Yergin. "Is it quickly being exploited? Not especially. Why? Because we have here a near-perfect example of obstacles being not technical, but almost entirely institutional and organizational."

One obstacle is achieving a practical working relationship with the electric utility whereby an industry can buy electricity when too little is generated by the industry’s power plant and sell electricity back to the utility when excess electricity is generated. This is precisely the arrangement worked out between Regency Square Shopping Center and the Jacksonville Electric Authority. A comparable relationship would be needed between a large manufacturing plant with cogeneration capacity and a power company.

Until recently such arrangements were rare, because electric rates were low for large-scale users and because utilities were less than eager to condone, much less encourage cogeneration. Some industries also held back because generating electricity and delivering it by agreement to a utility grid could result in
the industry being declared a utility with more arrays of regulations to monitor and more mountains of forms to process. The National Energy Act of 1978 began removing weeds from this thicket and simplifying matters to promote industrial cogeneration. Industries are in little peril of being publicly denigrated as utilities, and the utilities are increasingly hospitable to electricity from outside sources to help meet the electrical demands of the 1980s.

"Slowly, the regulatory system is adapting to the needs of conservation in general, and electricity rates are in the process of being revised so that they encourage, rather than discourage, cogeneration," wrote Yergin. "Altogether, it may be economically possible to cut industrial energy use by more than a third through cogeneration and conservation efforts." As much as $40-billion in total capital investment could be saved by industry with emphasis on cogeneration and conservation compared with the capital investments necessary with conventional energy sources. [11]

Some American companies do not fit generalizations describing the difficulties of cogeneration. These companies turn problems into opportunities. One of the most conspicuous energy saving records among American businesses was compiled by a company whose productivity makes it one of the three largest energy consumers in the United States. Through cogeneration and what the company calls "the war on Btus," this organization may also be among the most successful energy savers in the world.

Dow Chemical Company

Alcoa, U.S. Steel, and Dow Chemical are the nation's biggest energy consumers because of high productivity. All three have responsible records of energy use and conservation, but Dow Chemical has been a notable example of energy frugality nearly 80 years.

Dow's "war on Btus" began early in the 20th century when
the company founder, Herbert H. Dow, applied steam from a
turbine generator to obtain salt for Dow’s first chlorine-caustic
cells. Dow founded his company at Midland, Michigan in 1897
to produce bleach from chlorine. That beginning prospered
into the worldwide chemical manufacturing operation Dow is
today. Dow personally received almost 100 patents and was a
leader in many fields of industrial chemistry. When Herbert
Dow died in 1930, his work had helped give the U.S. world-
wide prominence in chemical manufacturing. When he started,
the U.S. was unimportant and little known in the field.

Innovation was the hallmark of Dow’s scientific and business
effort. Simply reproducing established products for a profit
held minimum interest. Dow wanted to pioneer new products
and fields of chemistry. In addition to technical chemistry, Dow
also pioneered improvements in chemical manufacturing proc-
esses. And he was one of the world’s earliest energy conserva-
tion enthusiasts. Dow and his plant manager in Midland, Merle
Newkirk, became celebrated as “nuts on power efficiency.”

Decades before others were concerned, Herbert Dow empha-
sized getting the most out of energy consumed and using it with
all the managerial wisdom available. Dow applied the cogenera-
tion principle when he used steam from a turbine generator
for an industrial process. By the 1920s cogeneration was a com-
pany commitment, and the founder’s energy attitude became a
company tradition that is still in effect over half a century after
Herbert Dow’s lifetime.

During a recent ten year period, Dow reduced energy con-
sumption per pound of product about 25 percent. “The co-
generation principle has grown to the point where millions of
pounds per hour of process steam in the Midland Plant are
produced via cogeneration,” reported Paul E. Kline, Dow Man-
ger of Energy Planning and Development. [12]

Very high-pressure superheated steam is passed through tur-
bines to produce electricity. Then low-pressure and medium
pressure steam from the turbines is piped to various chemical
processes.

Cogeneration not only saves energy for the company at the
large Midland industrial complex. Cogeneration is also in effect at Dow plants in California, Louisiana, Texas, and other parts of the world. The company’s practice for decades—thanks to the foresight and practicality of Herbert H. Dow—has been to use excess steam for processes instead of releasing it into the environment. What is thermal pollution one place is profitable energy another, and Dow has known the difference since the early 1900s.

In 1979, the difference in fuel input with Dow’s system at the Midland plant versus separate steam and power generation would be approximately 3 trillion Btus, the equivalent of 500,000 barrels of fuel oil, according to Paul Kline.

“Cogeneration is a way of life at Dow,” Kline added.

J. E. Mitchell, Director of Corporate Planning at Dow, called the 1973–1980 period the “Arab era” with its “scrambling worldwide fight for hydrocarbons” which still threatens companies in the U.S. and elsewhere. Mitchell convinced Dow management in the 1970s that “the only short-term solution is intensive conservation effort.”

“Dow’s efforts went from the simplest kind of housekeeping (turning off motors when not needed) to retrofitting (putting in heat exchangers) to designing entirely new plants that yield more product with less energy.” [13]

One Dow executive said, “Most things in energy conservation are not based on new knowledge, but rather the applying of knowledge we already have in a different environment.” Cogeneration is clearly an instance of applying such knowledge. The fact is Dow had been applying this knowledge steadily long before the hydrocarbon scramble.

Even with large-scale cogeneration and further conservation efforts, a point of lesser returns inevitably is reached. When all the unneeded motors and electric lights are turned off, you can’t save additional energy that way. In this connection Mitchell said, “There are no gimmicks left for us. From here on, the only way to save Btus is by reengineering, by building new plants, by spending more capital. The easy part is over.”

Saving more energy may be tougher now, but the Herbert H.
Dow tradition is still going strong at his company. Yergin pointed out that the company with relatively little capital investment increased energy productivity 40 percent and contributed to company profits while doing so. [13]

New wrinkles in cogeneration are also ahead for Dow, proving that innovation is still on-the-job in mid-Michigan. Dow may be part of a solution to the problem of creating an effective working relationship between industry and a large utility with energy efficiency as the outcome. In the 1980s cogeneration at Dow will take a new turn when for the first time the company will join an electric utility, Consumers Power Company, in a remarkable nuclear cogeneration partnership.

REFERENCES


**ATOMIC HEAT**

During the mid-1980s, some of the equipment used in 1981 to cogenerate steam and electricity for Dow Chemical Company’s Midland, Michigan facilities will go on standby and transfer the massive task of supplying energy for Dow operations to the rapidly splitting nuclei of steam.


In 1984 the Dow Chemical Division is scheduled to purchase its steam requirements from the Consumers Power Nuclear Plant. This steam will also be cogenerated. High-pressure steam will pass through the Consumers Power turbines to generate electricity for the network. Medium-pressure steam will be extracted from the turbine and sent
Nuclear Cogeneration

Enough of this. Newton forgive me. You found the only way that, in your day, was at all possible for a man of the highest powers of intellect and creativity. The concepts that you created still dominate the way we think in physics, although we now know that they must be replaced by others farther removed from the sphere of immediate experience if we want to try for a more profound understanding of the way things are interrelated.

Albert Einstein [1]

ATOMIC HEAT

During the mid-1980s, some of the equipment used in 1981 to cogenerate steam and electricity for Dow Chemical Company’s Midland, Michigan facilities will go on standby and transfer the massive task of supplying energy for Dow operations to the rapidly splitting nuclei of atoms.

Paul E. Kline, Dow Manager of Energy Planning and Development, wrote in 1980,

In 1984 the Dow Michigan Division is scheduled to purchase its steam requirements from the Consumers Power Nuclear Plant. This steam will also be cogenerated. High-pressure steam will pass through the Consumers Power turbines to generate electricity for the network. Medium-pressure steam will be extracted from this turbine and sent
to Dow. In addition, a portion of the medium-pressure steam will pass through a Dow turbine to produce electricity and low-pressure steam for heating. Cogeneration will continue to be a major energy saver. [2]

Nuclear cogeneration has been widely discussed, and some progress toward making it a reality has occurred in Europe. The Midland Nuclear Plant, now being built by the Bechtel Power Corporation for Consumers Power Company, is expected to be the first cogeneration nuclear operation in the United States. Giving nuclear power this dual role is viewed by the builders and the potential consumers at Dow Chemical as an important way to prevent energy waste, reduce cost, and promote energy efficiency.

The Midland Nuclear Plant is well along in construction on a thousand acre site near the Tittabawassee River, partially in Midland, Michigan, and partially in Midland Township. Visible across the river from the nuclear site are the factory buildings of Dow Chemical Company that will be supplied with steam when the Midland Nuclear Plant starts delivering cogenerated electricity and steam upon completion in the 1980s.

BACKGROUND DATA ON THE MIDLAND NUCLEAR PLANT [3]

Reactors: The plant will contain two reactors, each weighing 440 tons and measuring 8 inches thick, 50 feet high and 16.5 feet in diameter.

Power Output:

- Reactor Unit #1: 2468 megawatts (MW) thermal; 504 MW electric. Capable of supplying up to 4 million pounds per hour of steam to Dow Chemical Company.
- Reactor Unit #2: 2468 megawatts (MW) thermal; 852 MW electric.
Nuclear Fuel Charge: 93.1 metric tons uranium oxide in each core; average enrichment to 2.849% U-235.

Each reactor core with 36,816 fuel rods, in 177 assemblies, each 13 feet long and 8 inches by 8 inches.

Control Rods: 69 assemblies with 17 rods per assembly in each reactor to control the rate of fissioning.

Reactor Coolant Pumps: 4 pumps per unit. Each pump is powered by a 9000 hp, 6600 volt motor. Each can pump 88,000 gallons per minute of water through primary loop.

Steam Generators: 572-ton, 73-foot tall, 12.5-foot diameter shell and tube heat exchangers to transfer hot water in primary loop into steam in secondary loop. Two steam generators per unit: 15,500 tubes, 5/8” diameter, per steam generator.

Pressurizer: 52-ton, 45-foot tall vessel to keep primary loop under 2185 psi operating pressure. Allows water to be heated to 555° F at reactor inlet and to 602° F at reactor outlet without flashing to steam.

Evaporator Building: Contains heat exchanger system that will transfer heat from Consumers Power Company steam to Dow condensate and produce more steam for return to Dow. Systems include 11 low-pressure evaporators (will produce up to 3.6 million pounds/hour of 175 psi steam) and 2 high-pressure evaporators (will produce up to 400,000 pounds/hour of 600 psi steam). Each evaporator is served by feedwater heaters to pre-heat Dow condensate.

Turbine-Generator Building: Unit 1 Turbine-Generator: Up to 9,620,000 pounds/hour. 566° temperature, 900 psi pressure steam directed against rotor of high-pressure turbine stage, then against single low-pressure stage. Rotor spinning at constant 1800 rpm will allow generator to produce up to 504 megawatts of electricity at 23,000 volts. Voltage increased to 345,000 volts at main station transformer.

Unit 2 Turbine-Generator: Up to 9,770,000 pounds/hour, 566° temperature, 900 psi pressure steam directed against rotor of high-pressure and two low-pressure turbine stages. Rotor spinning at constant 1800 rpm will allow generator to produce up to 852 megawatts of electricity at 23,000 volts. Voltage increased to 345,000 volts at main station transformer.
COGENERATION AND DISTRICT HEATING

Cooling Pond: 880-acre pond, capacity of 4 billion gallons of water, used to cool plant condenser and provide service water to cool certain pumps, bearings and components. Cooling pond does not cool the nuclear reactor. Water pumped at flow rate of 264,000 gallons per minute through 72-inch diameter circulating water pipe for Unit 1 condenser and 390,000 gallons per minute through 96-inch diameter circulating water pipe for Unit 2 condenser.

Tank Farm: Two 500,000-gallon capacity tanks store borated water for use in emergency core cooling system for reactor. One 300,000-gallon capacity tank used for makeup in the primary reactor loop and one 70,000-gallon capacity tank for auxiliary building utility water.

Diesel Generators: Four standby engines to provide emergency electrical power when both nuclear units shut down and backup power supplies are not available. Each 57,199 cu. in. V-12 engine can supply 5.25 MW electric. Two needed to run entire plant. Each complete diesel generator weighs 137 tons.

EXAMINING A CONSTRUCTION SITE

“We expect this to be the most efficient nuclear plant in the world because of the arrangement between Dow Chemical and Consumers Power. Heat will be used that goes to waste elsewhere,” said Doug Richards of the Consumers Power Company staff. Richards led our group on a highly detailed inspection of the Midland Nuclear Plant and its cogeneration facilities. The author was part of a group assigned to help officials in the Midland area determine ways of using vast amounts of thermal energy potentially available from the nuclear plant as a result of the cogeneration arrangement with Dow. The group was organized and coordinated by the Michigan Energy and Resource Research Association (MERRA). Our assignment was to study industrial and agricultural applications of cogeneration in the area and make specific recommendations for using the
heat that should start surging from the activated reactors in the mid-1980s.

The need for the study resulted from Dow’s recognition that it would not require all the 4 million pounds of steam the Midland Plant would be able to supply each hour. R. A. Gaska, a Dow Manager, wrote, “Consumers will be supplying steam to Dow in quantities greater than our projected needs. Therefore, we would be interested in identifying customers, projects or opportunities that might make use of this excess steam (up to 2.0 million pounds/hour).” [4]

This offered an exceptional district heating and industrial cogeneration opportunity to the area. Group discussions focused on the possibilities of utilizing the steam for an industrial park, residential and commercial district heating, agricultural greenhouse operations, laboratories, and related options.

Learning in detail about the Midland Nuclear Plant was a crucial early need for background to complete the cogeneration feasibility study. In 1981, the nuclear plant construction site was one of the busiest places in America, rivalling perhaps the floor of the New York Stock Exchange. All the plant’s physical structures were in position. Now came the awesome hurdle of wiring, installing myriad controls, hooking up computers, and readying all the intricate paraphernalia that precede bringing in the atomic fuel and going critical.

“The nuclear industry is probably the most scrutinized industry in the country, yet is probably the safest,” claimed Richards. “There have been no deaths or serious injuries attributable to the operation of commercial nuclear power plants in the United States. Critical structures here have to be made tornado-proof, earthquake-proof, and missile proof. . . . It is mind-boggling to see how well nuclear plants are constructed compared to fossil fuel plants. Government regulations require that nuclear plants must withstand not only predictable but hypothetical accidents as well. Numerous safety and redundant systems are built in.”

Since human misjudgments apparently were part of the problem at the Three Mile Island nuclear accident, Richards was
asked if the Midland plant has been made “people-proof.” He acknowledged that is still a challenge, though in the design constraints there are now protections even against operator errors. “It is not a zero risk industry,” acknowledged Richards, “but what industry is?”

Certainly safety-awareness is everywhere you turn at the Midland Plant, and reducing risk is the main activity that will keep thousands of workers busy the next several years getting the plant ready for operations. Bringing nuclear fission as close to zero risk as possible is the overriding objective of the control systems, the shelters, the construction features, the inspections, the systematic effort throughout to anticipate every conceivable problem and to solve it in advance.

"WARM" COOLING POND

The 880-acre cooling pond, 4.7 miles in circumference with an average depth of 14-feet, is one of the key features of the plant design used at Midland. The pond has a designed capacity of 4-billion gallons of water, and its essential job will be to cool the plant condenser and other critical apparatus. Water will fill the pond, on an elaborately controlled basis, from the Tittabawassee River. The presence of the river—and of the Dow Midland Plant with its need for cogeneration steam—helped pinpoint the site as an appropriate one for nuclear cogeneration.

The cooling pond is intended to hold sufficient water for 100 days of plant operations. This period should carry the plant through occasional drouth periods and the summer months when low water conditions in the river prevail. Water cannot be withdrawn from the river except during periods of high flow.

Cooling pond temperatures during operations will range from 60–90°F, depending on the season. The point should be stressed that cooling pond water does not cool the nuclear reactor and it never has contact with uranium or other radioactive materials. Water circulates between the plant and the pond in a continuous loop cycle. This makes the pond self-sufficient
Figure 9-1. Midland operating cycle.
for long periods and protects against putting a strain on the Tittabawassee River.

A 60-acre section of the cooling pond is separated from the other sections. This water will be preserved as emergency water for the plant in case of sudden need.

Early signs (initial filling was completed in late 1979) are that many birds may learn to appreciate the warm hospitality of a nuclear plant. Ducks and geese have already been attracted to the pond. With 60° F water, freezing of the pond is not expected even on the worst days of winter. Birds are welcome, but fish are another story. They clog the pumps.

15,000 HOT METAL TUBES

Nuclear energy people like to startle you with dramatic comparisons. Example: “The approximately 30 tons of uranium fuel that will be consumed annually by each of the Midland Plant’s reactors will generate as much electricity as 2.2 million tons of coal, that is, 22,000 railcar loads.”

Nuclear proponents hope the reader will think carefully about the inevitable pollutants generated by 2.2 million tons of coal.

At the Midland Plant, our inspection group saw the Containment Building, the Evaporator Building, and the immense Control Room which will oversee and operate the entire plant.

The process is in every atomic primer and is now learned in grade schools: Atomic fission in the reactors produces heat that is transferred to water passing around nuclear fuel in the Primary Loop. This heated water—in over 15,000 hot metal tubes—by means of heat exchangers produces steam for turbine operations.

Safety Features: Water heated by the reactors never contacts water that is converted to steam for the turbines.

Heating water in the Containment Building with heat from atomic fission and using this water to generate steam for the turbines is the whole purpose of the plant, the labors of thousands for several years, and enormous investments. The com-
plexities, delays, and sheer plodding meticulousness of constructing a nuclear power operation today are summarized in a sense by the fact that Consumers Power Company first announced the building of the Midland Plant in 1967. The plant is supposed to begin operations in 1984, 17 years later. Whatever other criticisms can be made of the nuclear option, and the list is long, there seems no basis for the criticism that the nuclear industry moves too hastily.

If haste does make waste, observers can rest easy on that score concerning the Midland Nuclear Plant. Become one of the 12,000 visitors who tour the site annually, and you'll discover as our group did that nothing is done in haste and nothing is half-done. Or so it appears, impressively.

The large turbines at Midland function in the same way as turbines at a fossil plant. The difference is that instead of coal, oil, or gas combustion, nuclear fission supplies the steam needed to operate the turbines and produce electricity.

4 MILLION POUNDS OF STEAM EVERY HOUR

The inspecting group was particularly interested in details concerning the cogeneration functions of the plant.

In addition to generating electricity, Reactor Unit #1 will be capable of supplying up to 4 million pounds of steam per hour for use by Dow Chemical Company and for alternate applications in the area. Piping systems to deliver process steam and to receive condensate will connect the Midland Nuclear Plant and the Dow plants across the river. The breakdown on the 4 million pounds of steam is:

- 3,400,000 pounds of low-pressure steam
- 600,000 pounds of high-pressure steam

Cogeneration will make the plant one of the most efficient nuclear plants in the world. Reactor Unit #1 will be about 42% energy-efficient as a result of cogeneration. This contrasts with typical 30% efficiency in the absence of cogeneration.
In operation, part of the steam generated by Reactor Unit #1 will be drawn off to the Evaporator Building for transfer to Dow via piping that crosses the Tittabawassee River in two places. The condensate then returns from Dow for conversion to steam again in a continuous cycle.

Additional piping networks can be installed to accommodate the surplus steam, unneeded by Dow, when local district heating or industrial process applications are determined.

Dow Chemical will have its own power generating facilities available to fall back on in case of interruption in service from the nuclear plant. The question of backup power for cogeneration steam used in additional applications was one of those the study group needed to weigh and answer. Other questions included:

- Size and makeup of the service area?
- Residential density?
- What cogeneration heating medium would be available: steam, hot water, or steam and hot water?
- Availability of cooling water?
- Plant costs to take advantage of the cogeneration opportunity?

These questions led to others as the group sought economically feasible, commercially appropriate, and technically valid ways to use the available steam rather than to let it go unused and be wasted.

This experience made clear that advance planning is an indispensable prerequisite in connection with developments on the scale imposed by cogeneration and district heating projects. In the case of nuclear cogeneration, there was one further obligation: reassuring the public.

EMPHASIS ON EDUCATION

“We give people the facts so they are equipped to make their own judgments,” said Doug Richards, whose staff group at
Consumers Power Company shows as many as 12,000 people through the nuclear plant annually. The visitors range from Washington officials to energy V.I.P.s from around the world to high school or junior high school science classes. Yet even with facts and more facts, after Three Mile Island, public fears, doubts, and misunderstandings continue to haunt the nuclear industry.

Because of negative publicity and a general lack of realistic information, public instruction seemed a basic need of the proposed cogeneration activity in the Midland, Michigan area. The people in the area are accustomed to large industry (Dow Chemical) and are hospitable to new technology. Nevertheless, group discussions stressed the value of impressing on the public the fact that the thermal heating medium delivered from the plant to Dow and other users would never have contact with the nuclear fission process or radioactive material. This would provide fundamental reassurance that the products or services derived from the thermal energy delivered by the plant were as safe as those using heat from any nonnuclear source.

SAFE IF STRUCK BY FLYING SAUCERS

The cumulative impression at the Midland Nuclear Plant is that everything human effort and ingenuity can accomplish has been done to guarantee operational safety. A multitude of controls throughout the facilities protect against accidents, mishaps, or errors. To the initial epidemic of controls, a new generation of controls followed Three Mile Island. More redundancy systems have added to the time and cost of construction, but have admittedly extended the safety factor still farther into the unknown.

Safety-related construction caused delays, but this is characteristic of nuclear installations. Better safe than sorry is another hoary proverb, readily accepted as pragmatic wisdom in the nuclear industry.

An illustration of redundancy for the sake of security is the
requirement for a dual set of cables. The plant originally was designed to function with 5 million feet of cable. The required extra set increased that to 10 million feet of cable. Engineers then had the problem of finding the space, and managing the installation.

The impression is strong that whatever is possible has been done to make the plant safe. The impression is also strong that the plant is a thousand acre computer with an overall operational complexity conspicuously susceptible to the "law" that if anything can go wrong it will. However, if there are countless places where that could happen, built-in emergency therapies, systems, and apparatus are on-call to identify and isolate every problem promptly and handle it securely.

Safety measures include a construction method of putting pressure on finished structures in a way that will condense buildings slightly, thus increasing their structural strength so they can withstand the impact of being struck by an airliner, or even perhaps an invader from space. Safety provisions are heartening, but they don't answer all questions, for instance the question: Will all of them work? The most foolproof precautions cannot vanquish apprehensions, perhaps because the precautions are tangible and real while the apprehensions are vague, suppositional, and emotional.

Some scientists and informed nonscientists argue that nuclear plants are simply too great a gamble at this point, that our energy development efforts should aim elsewhere—toward the sun, or coal, or cogeneration from municipal wastes, or biomass, or geothermal, or hydro, or fusion, or all of the above.

Other scientists and informed nonscientists just as vigorously insist the nuclear option cannot be delayed, that for many parts of the world it is the only realistic alternative right now to continued total dependence on the hydrocarbon habit. These defenders of nuclear energy accurately emphasize the safety record of the industry, and they warn that to wait for all technical problems to be solved means in effect that those problems will never be solved. They may, however, be solved in the course of practical efforts to benefit from what is already known while
working carefully for answers to nuclear waste disposal and other hanging nuclear issues.

The testimony in Europe and at Midland, Michigan indicates that many are going ahead with nuclear development including nuclear cogeneration. The technology of cogeneration and district heating easily adapts to the new energy source. An advantage of a district heating network is that any available energy can be turned on at the central heating source with the same results. The network won’t ask how the steam or hot water was produced but will simply use it. In the course of things, if one fuel runs short, the district heating operation can continue as before simply by substituting another fuel. This flexibility is a feature of district heating that can be particularly valuable during the present and future period of energy uncertainties.

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Making District Heating Competitive

Much more of the prosperity of a winter country depends on the plenty and cheapness of fuel than is generally imagined. In travelling I have observed, that in those parts where the inhabitants can have neither wood, nor coal, nor turf, but at excessive prices, the working people live in miserable hovels, are ragged, and have nothing comfortable about them. But when fuel is cheap (or where they have the art of managing it to advantage) they are well furnished with necessaries, and have decent habitations.

Benjamin Franklin
Writing at sea, 1785

NECESSITY OF BROAD COOPERATION

The “art of managing fuel to advantage” could be appropriated as a modern definition for district heating. Founding Father Franklin wrote many things that have the ring of contemporary wisdom. When he wrote about energy he especially seems to be looking over our shoulders.

Franklin praised the energy-poor Chinese “for making a little fire go as far as possible,” and that phrase too aptly summarizes the intent and effect of district heating, especially when associated with the energy efficiencies of cogeneration.
In 1745, three years after he perfected what he called the Pennsylvania Fireplace but history has insisted on calling the Franklin Stove, Franklin warned his fellow Americans that wood, the common fuel, was growing “scarcer and dearer” and “any new proposal for saving the wood, and for lessening the charge, and augmenting the benefit of fire, by some particular method of making and managing it, may at least be worth consideration.”

Franklin included this statement in a charming, funny, informative sales pamphlet he wrote to help market the Franklin Stove. The inventor, incidentally, refused to profit from sales of the stove himself. He wanted his countrymen to benefit from the stove, but his own satisfaction came from the challenge of inventing it. “As we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours, and this we should do freely and generously.” [1]

District heating in the 1980s is a good example of an invention that the efforts of many through the decades have perfected and that is available to help us augment the benefit of fire. It “may at least be worth consideration.”

The development of district heating in the United States has regionally been broadened and somewhat accelerated, but nationally the U.S. has actually done little to accelerate the general use of this versatile technology. There are few challenges to the claims made about the effectiveness of district heating once the system is in place. Clearly it does reduce energy use in comparison with conventional methods. Clearly it does achieve cleaner air. But there are challenges nevertheless, and to a large extent, they have been insurmountable in the United States except for scattered communities, enterprises, institutions, and industries.

How can district heating be made competitive? How can those who admit the future need for its advantages be persuaded to invest current funds and efforts in bringing it about?

Of course there is no single or simple answer to such questions. Making district heating through cogeneration an enthusi-
astic American choice with vigorous national effort behind it requires reiterating the benefits until those who hear beg for relief from the propaganda and then act. It requires innovative financing. It requires a high degree of cooperation and understanding among federal, state, and local leaders, businessmen, and the public. It requires in the United States more volunteer “benefactors of mankind,” Franklin’s phrase for those who do something about supplying fuel and helping citizens use it wisely.

These are general comments, obviously, and notoriously difficult to apply. Fortunately, in connection with cogeneration and district heating, there is no shortage of specific things to do and concrete facts to stress in order to make district heating competitive.

GETTING THE COST DOWN

Technical advances such as more economical piping and more efficient methods of installing it will help reduce the prohibitive start-up costs of new systems. An estimated 55–75 percent of start-up costs is for transmission and distribution networks.

Producing thermal energy and delivering it less expensively will make district heating more competitive with oil, gas, or electric heating. Alternate fuels such as municipal waste and sewage sludge might give district heating the economic nudge required to make it a practical economic choice as well as a choice for energy efficiency.

It is unrealistic to talk about energy efficiency with district heating if the cost of the technology is substantially greater than the cost of competing technologies. Like it or not, we know what ultimately talks loudest in such matters: Money talks. The costs of the marketplace determine what people will use. Automobile manufacturers can plead until they are red, white, and blue in the face, “Buy American, not Oriental.” But American car buyers will continue to buy Japanese
cars, or any other international cars, as long as they are the best buy.

Make a better mousetrap, suggested Emerson, and the world will beat a path to your door. He didn’t say make an American mousetrap, but a better mousetrap. To be judged better, district heating must cost less now, or it must be made so obvious that it costs less in the long-run only fools would hesitate to use it. And remember sometimes even fools get smarter if patiently instructed.

“The incentive to the investment and the capital cost required in converting steam heated buildings to hot water must be a lower energy price from the district heating utility than if the building was heated by gas or light oil,” wrote Erik Wahlman. [2]

Wahlman, a Swedish expert on district heating, had much relevant advice for American district heating developers. He noted that it is considerably more economical to introduce district heating in new areas and concentrate later on older parts of the community. He stressed the need to make tax systems accommodate and encourage the introduction of district heating. Tax incentives, stated Wahlman, should apply both to utilities and to customers.

These are basic ideas aimed at helping Americans join Europeans in gaining energy advantage from cogeneration/district heating. Despite the heavy initial investment, an efficient district heating system will pay for itself in a matter of years. As energy prices climb, the payoff period may grow shorter. This is a fact that should be included in assessing the competitiveness of district heating.

HANDLING THE FINANCIAL BURDEN

What holds back district heating development are not technical considerations, but social, political, and financial factors. This claim is so widely repeated, it may be true. Helge E. Nurmi, a former president of the International District Heating Association, said, “In attempting to analyze why the known
benefits of district heating have not produced industry growth, no single factor stands out. District heating systems are primarily owned by local government, investor-owned utilities, and state and privately supported universities . . . some means of relief is required for the funding.” [3]

European observers such as Wahlman, American utility representatives, and local communities have traditionally looked to the federal government for active involvement in district heating development. Active involvement is a euphemistic phrase for federal funds.

Certainly the federal government’s responsibility to establish a viable and realistic national energy policy should include strong, direct support for energy programs that can benefit millions, save energy, save money, and help the environment—in other words, district heating. At the same time, local communities, utility representatives, and the man on the street do themselves a disservice if they simply wait for the federal government to act. Federal governments do not always act, but it will be cold in the winter of 1990 just the same at Newark, New York, Pittsburgh, Detroit, St. Paul, Chicago, et al. Sometimes it would seem prudent for citizens and their civic leaders and their city councils to apply the revised, optimistic maxim: “Washington helps those who help themselves.”

With this said, it must also be said that district heating projects on a widespread national scale probably will never develop without strong government support, city through federal. The projects are public in scope, and government is the business arm of the public.

District heating systems are capital intensive, and one difficulty they have under the utility umbrella is that historically they have paid low profits or in many cases no profits. This makes it difficult for district heating systems to compete with more profitable utility projects for scarce company resources. Utility regulatory restrictions can also obstruct investment in district heating. To finance district heating, new financing approaches are essential and these require toleration if not ardent support from regulatory commissions.

Some states have made progress in simplifying regulation of
utilities and making it easier to facilitate investment in district heating. There is no standard, cookbook way to finance large energy projects. Each state, indeed each community, or even neighborhood, must handle the financial issues individually. What works one place, may harvest only laughter or tears another place.

Municipalities today often adopt the Integrated Community Energy Systems approach. They develop district heating systems as community projects financed with whatever mix of traditional funding mechanisms can be arranged (e.g., tax-exempt industrial revenue bonds, special revenue bonds, municipal general obligation bonds, corporate bonding, government programs). The formation of municipal joint action agencies, energy committees, energy action groups, are another trend of the times. Witness the St. Paul not-for-profit district heating corporation which was set up to “serve as a task force that could act independently of state and local government to provide the technical and economic analysis required.”

This development company grew out of a study conducted on the institutional issues involved to develop cogenerated hot water district heating for the Twin Cities. “Hot water district heating services must be properly priced to compete in the marketplace of several alternative energy heating sources, including electricity, which is a co-product of the district heating cogeneration plant,” the report stated. [4].

The Twin Cities experience may not provide a map for other areas, but it does offer useful checkpoints for consideration.

Two ownership options were evaluated:

1. Private Owner/Private Operator
2. Public Owner/Public Operator

After considering scenarios for different economic conditions, a steering committee with local and state representation decided the risk was “too great for any party to assume the development burden.” The not-for-profit company was the result, with the job of determining on the basis of investment strategy,
the rate structure, and potential returns, the optimum way to proceed with financing and development.

The development company provides needed liaison among the groups involved, including the public, government, and financial. The institutional issues study in St. Paul learned that, “Potential customers are hesitant to commit to long-term contracts for cogenerated thermal energy without knowing the specifics of delivered cost and operating reliability. These potential barriers cannot be fully resolved without state and local government commitments to the cost and conservation efficiencies of cogenerated district heating, and policies which resolve potential institutional barriers.” [4]

One community approach to district heating financing that has been advocated is the employment of investment banking institutions to arrange an appropriate financial package. Such bankers are somewhat like concert managers for money. They find out where funds are and then book them for large-scale municipal projects such as energy development operations. Performing a district heating concerto based on a local theme would be well within the province of these international money conductors.

There is no definitive, straightforward way to finance projects of this magnitude. Again it is a matter of pushing on doors until the right ones open. What works in one area with one group of citizens could prove totally inadequate somewhere else. Perhaps the best answer in connection with the financial challenge is to demonstrate the advantageous aspects of district heating so irresistibly, available funds themselves almost beg to be included in the development package. This is not a facetious possibility. Ultimately the success of district heating in America will come for the same reasons it came in Europe: When people recognize generally that reducing fuel waste, improving air quality, and establishing an energy system that will have a sustaining, stabilizing influence for many years are valuable things to do, then district heating by means of cogeneration will be seen as energy opportunity they literally cannot afford to pass up any longer.
ISSUES IN PLANNING

The following have been identified as important concerns to consider when planning district heating programs. [3]

Investor-User Confidence

The investor must be confident of a fair return. This issue alone has inhibited efforts to arrange private financing. Utilities and other companies with limited capital available logically put it where they think it will do them the most good. The answer to this bottom line question is seldom district heating.

Yergin contends that public policy must help overcome investment barriers as well as others standing as obstacles to large-scale conservation activities. For example, while the 1978 National Energy Act gives a 10 percent tax credit for conservation investment, Yergin thinks tax credits should be as high as 40 percent. Also, he wrote, “Accelerated depreciation and energy-conservation loans are required. These are especially important in a period of lagging economic confidence, high inflation, high interest rates, and high uncertainty—and consequent low investment.” [5]

Yergin warned that rising energy prices simply could not be relied on to make district heating or other conservation investments sufficiently attractive for predictable action. This is true because investors, banks, and corporations have many other concerns as well as energy conservation. Most American corporations have recognized the importance of conserving energy as prices rise, and many have done so impressively simply through internal action. Gillette reduced energy use 30% in seven years with little capital investment. Cameron Beers, Gillette’s corporate energy manager, attributed the savings to “a sum total of a variety of little things. We keep thinking we’ve just about done everything, but new ideas keep springing up.” [5]

With rising prices, we can expect companies to keep turn-
ing off unneeded lights and to control the allowable level of space conditioning, but, Yergin wrote, “Just because energy prices are high does not mean investments will be made. For, at any given time, there are many more claims on corporate funds than there are funds.”

Making cogeneration and district heating more effective in claiming a healthy share of available funds is essential. How? The same way any other investment is justified: By proving it is the best buy now, not 20 years from now.

Customer Commitments

Long-term contracts are vital to assure district heating developments operating revenue and seed money for system growth. The success of district heating in Europe is accomplished in part through guaranteed user participation. Various European systems finance system growth with fees paid by customers in new buildings at the time of hook-up, as well as regular payments by subscribers. The volume of participation must be high to make this feasible. A high level of participation is also achieved in the classic way: Making the service better than that offered by the competition, making it a superior choice for the customer in need of heat.

Competitive Prices

It may not be the wisest question human beings ask, sometimes it is plainly unwise or irrelevant. But it must be the most often asked question: “How much is it?” Proving that district heating means competitively priced thermal energy over the long haul is a key element.

Hook-up Incentives

Voluntary programs work when incentives are sufficient to attract participants. The automobile rebate program was not
a sudden hysterical illustration of corporate generosity. It was
incentive marketing, pure and simple. Discount coupons are
used to encourage choosing this soap rather than that soap.
Monetary incentives are not the only ones available. In the
case of district heating, convenience can be an incentive. Offer-
ing the customer an efficient package with all the pain removed
from changing over to district heating may help bring a favor-
able decision.

Utility Commitments

When the customer contracts for long-term participation, the
same contract must guarantee long-term service. This guarantee
must be supported by appropriate regulatory mechanisms so
the customer is assured he can’t be left with his house con-
ected to a piping network through which nothing passes ex-
cept unkept promises.

Effectively addressing these and related concerns in the plan-
ning stages of district heating programs can make implementa-
tion easier. Failure to address them may make the establish-
ment of a system impossible anywhere except on paper.

HOW GOVERNMENT CAN HELP

In 1980 the U.S. Department of Energy published guidelines
on district heating in America and gave three reasons federal,
state, and local government support must be effectively com-
bined to carry out new initiatives and gain energy benefits both
nationally and locally [6]:

1. District heating and cooling (virtually all using steam
rather than the more efficient hot water) currently sup-
plies only about one percent of the total U.S. demand for
space heating. The potential exists to expand this at least
tenfold.
2. The number of existing steam DHC systems is actually declining, and utilities are reluctant to invest capital for new systems or expansion of existing ones.

3. There are a number of existing barriers to potential DHC projects, such as economic, regulatory, institutional, environmental, and legal issues, that need to be resolved in order to accelerate implementation of district heating and cooling.

The guidelines/strategy identified four markets for district heating and cooling, each with varying technical, economic, and institutional characters:

- Densely populated urban areas.
- High-density building clusters (e.g., universities, shopping centers).
- Low-density residential areas.
- Industrial complexes requiring process heat at low temperatures.

The value of district heating systems in all four markets has been demonstrated repeatedly. Even residential areas are economically served by hot water district heating systems in Europe.

The report stressed the role of state governments in bringing district heating programs to fruition. The need for federal action or backup is evident as well to provide incentives and remove barriers, to offer technical and financial assistance, and to help nationally with coordinated exchange of information on district heating. A particularly significant national objective was establishment of a strong “technology program to assure that the maximum potential benefits can be attained in the long term.”

Federal action is considered necessary to promote national benefits that often do not coincide with specific corporate interests, to develop a supportive climate in the U.S. business community, and to stimulate acceleration of the district heating movement.
Less than a year after publication of these strategy guidelines on national district heating and cooling, new political objectives and policies at the federal level (the result of that U.S. phenomenon, the quadrennial quadrille known as “a change of administrations”) made the federal program uncertain and, at a minimum, meant delays.

The district heating opportunity and need, of course, didn’t disappear while politicians sorted out their priorities.

ADVANCING THE TECHNOLOGY

An important argument for cogeneration and district heating is that proven, workable technology is already available—no standing in line at the energy research laboratories for the slide-rule artisans to come up with something new. This is a familiar argument and true enough, but it falls short of the total truth, which is that even with an established technology, new improvements are not harmful. Technological progress can certainly enhance the economic viability of district heating.

Three factors tend to dominate the economic health of district heating systems: (1) heatload density, (2) annual load factor, (3) consumer connection rate. Each of the three is needed at a high level to make district heating systems economical. All three tend to complement each other. If the consumer connection rate is high, the annual load factor will be high. A good mix of industrial and residential consumers can help achieve an annual load factor and a heatload density that spell success for a district heating system.

The maximum number of potential users in the service areas should be connected to the system as rapidly as possible, so that revenues can be generated without long delays. For new buildings, the cost of heat-transfer equipment for district heating and cooling would generally be less than or comparable to the cost of individual boilers or furnaces. The cost of conversion in existing buildings would depend on the type and condition of the existing heating equip-
ment. If the existing system required replacement, the investment for conversion to district heating and cooling could be an attractive alternative. [6]

Whatever can be done technically to improve equipment or reduce cost will contribute to the overall attractiveness of district heating technology. Especially noteworthy, considering the high cost of the transmission and distribution system (>55%), would be development of low-cost, nonmetallic piping for district heating networks and associated improvements in piping installation techniques.

European research into better ways of transporting heat may prove useful to district heating development in the United States. Swedish scientists have focused particularly on the production of inexpensive, noncorroding warm water pipes designed to be laid directly in the ground, eliminating the need for expensive concrete ducts.

One area of Swedish pipe research involves pipes made from glass fiber–armored plastic. These pipes would be insulated with a cellular plastic and covered with a protective sheet. Another research thrust concerns pipes of reinforced concrete with an inner lining of plastic and plastic concrete to prevent hot water leaching of the concrete. A cast insulation surrounds the outside.

Ground water would not damage either of these pipes if the insulation should be damaged. Olszewski notes that “sliding telescopic joints with artificial rubber tightening rings could be used in place of expensive expansion joints yielding further cost savings.” [7]

The operating temperature for such pipes would be determined by the types of plastic and sealing method used. The German district heating industry has successfully used small glass fiber–armored pipes at the normal operating temperature of 130° C (266° F). The German pipes have solid joints and use a relatively inexpensive epoxy. Using a cheaper resin and telescopic joints might limit operating temperatures to approximately 100° C (212° F).
Swedish cost calculations indicate that the new piping technologies show a 40–50% cost savings compared to the conventional steel pipe in a concrete culvert method. These cost calculations also show savings of 20–40% compared to steel pipe installed above ground on concrete piers. Because of operating temperature limitations, these piping improvements would be utilized most effectively in reducing the distribution costs within the commercial-residential sub-region. [7]

Much of the remaining capital investment in a district heating system covers the central heating or cogeneration plant that supplies thermal energy, and also the cost of consumer equipment, which can be purchased outright by the customer or paid

Figure 10-1. Potential district heating distribution system for an apartment building. Many possible design configurations are feasible. This two-pipe hydronic distribution system supplies heating, ventilation, and air conditioning (known as an HVAC system). Hot water enters the building at 141° C (285° F), and chilled water enters at 6° C (43° F). A separate piping system distributes domestic hot water to each apartment. [7]
MAKING DISTRICT HEATING COMPETITIVE

for over a period of years in conjunction with periodical district heating bills.

When thermal energy (steam or hot water) is produced by a cogeneration installation, plant costs for district heating are shared with costs for generation of electricity, which can have a symbiotic effect for both. However, when an electricity-only plant is retrofitted to supply district heating, care is needed to assure equitable rates. The Commissioner at the Minnesota Public Utilities Commission, Katherine Sasseville, described the approach in her state: “When district heating is added to an electric utility, electric customers aren’t asked to pay more, while district heating users pay just the extra costs of the district heating operation. This benefits district heating when systems need help to get started, without requiring electric consumers to subsidize district heating development.” [8]

Reducing the cost of piping will expand the district heating market to include lower-density heat-load areas and dramatically improve the overall competitive picture for this energy distribution and conservation methodology.

More promising technological leads are certain to appear as Franklin’s “benefactors of mankind” aggressively apply their skills to cogeneration and district heating. Technical progress regularly occurs in the course of such development. Fortunately there is no way to prevent it. As they carry out practical applications, individuals get ideas, they observe, and sometimes they say, “There’s a better way to do this.” And sometimes they’re right.

Better uses of fuel, utilization of alternate fuels, improved methods of producing and delivering steam or hot water, more consistent cogeneration efficiencies in the use of fuel—all will advance to some extent, whether great or small, as district heating makes contact with the American future.

The important thing to guard against in connection with future development of the technology is assuming that energy costs alone will inevitably make superior efficiency prevail. Very little happens, except weather and taxes, simply because it must, or should. Cogeneration technology will become competitive
and will save America energy because and when energetic people decide to make it happen.

REFERENCES

New Directions

A prime example of the new wave of more efficient energy systems is the “cogeneration” equipment that industrial and commercial customers are beginning to install to make their own electricity with oil or gas. These on-site systems recapture the waste heat from their power generators to warm the building in winter, drive the air-conditioning system in summer and provide hot water the year round. And, in general, they consume no more oil or gas than the building would otherwise use. Utilities have generally resisted cooperating with such schemes, in large part, because the resulting loss of customers would erode revenues and force rate increases. But the alternative is to build more central power stations, which would force even bigger rate increases. In the minds of many, the sensible economics of cogeneration is sooner or later going to prevail.

A. J. Parisi [1]

NEW YORK STATE COGENERATION ACT OF 1980

Anthony J. Parisi, former energy correspondent of The New York Times, wrote in April 1981 about the declining demand for electricity in the United States. Slower economic growth was one reason, but more significant according to Parisi “has been the customer’s decision to shun high-priced energy.” This energy writer noted that one of the simplest ways to relieve
pressure on oil was happening widely: greater energy efficiency. "As last year's 4 percent drop in energy consumption demonstrated, Americans are learning to break the antiquated habit of wasting what is no longer cheap enough to waste," Parisi wrote. [1]

Cogeneration and district heating are increasingly recognized as a preferable way to achieve practical energy efficiency. Not only industrial and commercial organizations are starting to consider cogeneration, but also various states are trying to stimulate and encourage development. New York State is one of those not waiting for federal legislation. The New York State Cogeneration Act of 1980 states: "It is in the public interest to encourage the development of alternate energy production facilities and the development of cogeneration facilities in order to conserve our finite and expensive energy resources and to provide for their most efficient utilization."

This important legislation, which may set a pattern for other states, exempts "cogeneration facilities" from state and local permits, various construction requirements, and operational conditions (applicable environmental, worker protection, and federal laws are not exempted).

The New York Act requires the State Public Service Commission to encourage utilities to participate in cogeneration directly or through their subsidiaries. One provision is to require an electric or steam corporation to purchase or "wheel" electricity or thermal energy with "just and economically reasonable terms and conditions."

In the main, the New York legislation is designed to remove regulatory obstacles and to promote utility involvement. Existing utilities are permitted to organize amalgamated thermal systems and to finance them out of retained earnings. Under the Act, the state will promote the combined benefits of cogeneration and district heating through the statewide organization of multiple-user thermal energy districts.

This state activity is one among many nationwide taking cognizance of what can be done and what can be gained with this off-the-shelf technology.
One eagerly awaited result of intensified, broader U.S. activity, complementing international efforts, is accelerated technical progress. Cogeneration and district heating may be off-the-shelf, but greater energy and cost efficiencies will be sought and found. No one argues that what comes off that shelf can’t be improved. District cooling, for instance, is by no means as well advanced as district heating. Since cooling as well as heating is critical in many parts of the United States, perfecting absorptive air conditioning systems and equipment is a prime direction of future work. Retrofitting buildings that are not already centrally air-conditioned is costly. Technical progress will be sought in this area.

Many directions are currently being explored that show the growing vitality and significance of this simple and yet uniquely promising way to get the most from consumed fuel. In this connection, we can again consider district cooling. Since various sections of the United States have both heating and cooling demands because of severe winter (cold) and summer (hot) conditions, district cooling is a potential way to help cities with steam systems in operation achieve higher load factors and greater efficiency. U.S. steam systems have an average load factor of 33 percent. District cooling might beneficially contribute to better overall system performance.

Recent directions in district heating technology and implementation policies include the following:

WAYS TO STORE HEAT

From an energy efficiency viewpoint, storing heat is critical in cogenerated district heating systems. This is true because the peak load period for the district heating system and the peak load period for the electric generating plant generally are not the same. Thus, when the utility generates excess heat, if means were available to store it until the district heating system’s usage demand peaks, the least amount of energy would be wasted.
Both surface and underground storage methods have been studied. Surface storage in tanks is possible. Studies at the Bellingham, Washington district heating project based on cogeneration with the Intalco aluminum plant showed that surface storage "while expensive, is cost effective at or near system startup and is conveniently expandable in capacity for future growth." [2]

Storage underground in tanks provides greater insulation. Underground storage in aquifers or abandoned mines is also a potential future direction. At Bellingham, Washington, an abandoned coal mine was considered, but was rejected as too large during the first phase of the district heating project. The mine option is being held in abeyance and may be developed later.

"The decision to incorporate partial mine storage can be made after the first few years of system operation depending upon the penetration and growth rates actually achieved." [2]

Seasonal storage in aquifers is a promising direction. Water chilled in the winter would be stored in aquifers for summer air-conditioning use; while water heated during the summer would be available for winter heating.

An interesting project in this vein was announced for Bethel, Alaska. [3] During warm weather, water would be pumped from the aquifer for heating with exhaust thermal energy from the town's diesel generator. This heated water would then be pumped back into the aquifer and kept there until it is withdrawn in the winter for district heating needs. Heat exchangers can be used to establish a closed system that will keep foreign materials out of the underground storage area.

THE MUNICIPAL WASTE TREND

As previously discussed, the use of urban refuse as a fuel for district heating operations is an established and growing commitment in Europe. The identical logic is now invading North America more successfully than before.

For example, one of two new district heating developments
in Canada now being planned would have four cogenerating solid waste disposal plants to provide heating service, hot water, and electricity to a large new hospital complex on Prince Edward Island. The system would also deliver steam for district heating to other buildings in adjacent areas.

A second new development in Canada would provide a hot water district heating system to serve the residential needs of a proposed Toronto suburb, North Pickering. When implemented, these new developments will join steam-based district heating operations serving the downtown sections of London, Toronto, Vancouver, and Winnipeg.

Several U.S. cities are rapidly being alerted to the value of garbage as an energy source. In Pittsburgh, with the district heating system on the point of collapse, the chance of integrating it with a resource recovery plant has given the system a better fighting chance of hanging on. Nashville, Tennessee, Akron, Ohio, and Harrisburg, Pennsylvania are cities that have moved or are moving in this respect. Numerous other cities are in various stages of operation or development.

A 1981 report stated:

Relative to conventional fossil fuels, solid waste as an energy source is expected to become progressively cheaper with time. . . . Because of this developing differential in the cost to produce solid waste versus fossil fuel energy, resource recovery systems will be able to offer discounted steam prices while still realizing a system “profit” on their steam sales. In addition to the potential pricing benefits of solid waste-derived steam, this energy source also offers an insulation from future fossil fuel shortages, embargoes, and other interruptions. [4]

Table 11-1 contains a representative list of selected resource recovery systems either operating or under construction. Each system is designed to deliver steam, and collectively they “indicate a natural technological compatibility of resource recovery with district heating systems.” [4]

Among the approaches available to combine resource re-
Table 11-1. Resource Recovery Systems in the United States (Operating or Under Construction, A Representative Selection)

<table>
<thead>
<tr>
<th>Location</th>
<th>Steam Customer</th>
<th>Plant Size (Tons/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Little Rock, Arkansas</td>
<td>Koppers Company</td>
<td>100</td>
</tr>
<tr>
<td>Salem, Virginia</td>
<td>Mohawk Rubber</td>
<td>100</td>
</tr>
<tr>
<td>Auburn, Maine</td>
<td>Pioneer Plastics</td>
<td>200</td>
</tr>
<tr>
<td>Pittsfield, Massachusetts</td>
<td>Crane &amp; Company, Inc.</td>
<td>240</td>
</tr>
<tr>
<td>Chicago (Northwest), Illinois</td>
<td>Brach Candy</td>
<td>1600</td>
</tr>
<tr>
<td>Harrisburg, Pennsylvania</td>
<td>Pennsylvania Power &amp; Light</td>
<td>720</td>
</tr>
<tr>
<td>Nashville, Tennessee</td>
<td>City Steam Loop</td>
<td>720</td>
</tr>
<tr>
<td>Hampton, Virginia</td>
<td>NASA</td>
<td>200</td>
</tr>
<tr>
<td>Norfolk, Virginia</td>
<td>U.S. Navy</td>
<td>180</td>
</tr>
<tr>
<td>Saugus, Massachusetts</td>
<td>General Electric</td>
<td>1500</td>
</tr>
<tr>
<td>Akron, Ohio</td>
<td>City Steam Loop</td>
<td>1000</td>
</tr>
<tr>
<td>Albany, New York</td>
<td>State Steam Loop</td>
<td>750</td>
</tr>
</tbody>
</table>

Cogeneration and district heating is to use refuse-derived fuel (RDF), either fluff or densified, as a supplemental fuel in utility boilers. Fluff RDF facilities associated with municipal utility boilers are found at Ames, Iowa and Madison, Wisconsin. Combustion of unprocessed solid waste in boilers designed to use RDF as the primary fuel occurs in systems at Akron, Ohio and Hempstead, New York. These systems produce medium-temperature and medium-pressure steam suitable for industrial processes and heating applications though generally not for electricity production. Utility boilers using RDF, however, produce high-temperature and high-pressure steam for cogeneration of electricity and thermal energy applications. [4]

One of the most ambitious systems considered for U.S. development is the 3000 ton per day system recommended for construction at the Brooklyn Navy Yard to generate steam for the lower Manhattan steam loop. Equally important for the locations they will serve, but considerably smaller, are systems using modular incinerator units to provide heating and cooling at various universities and institutions nationwide. The Uni-
versity of New Hampshire, for example, receives steam from the Lamprey Regional Solid Waste Cooperative.

Although the cost of installing pipelines and building resource recovery plants is great, the cost of conventional fuel over a period of time is even greater. That is why municipal developments no longer qualify as “rare,” and state encouragement is spreading. The successful experience in communities that adopted the technology early is convincing others, including utilities. “A final set of constraints for resource recovery projects with district heating systems have their basis in the reluctance of utilities to believe that waste-derived energy is a reliable source,” wrote Barnett et al. “There is justification for such fears but, currently, well-designed resource recovery systems with adequate subsystem redundancy built in, are producing impressive track records for uninterrupted service. Nashville, for example, has been in operation for over seven years without a service interruption.” [4]

These authors note that resource recovery, district heating, and cogeneration are closely related and “ideally positioned” in many respects. “Solid waste is combusted to produce high pressure/temperature steam for the generation of electricity for in-house use and/or sale to the grid and then the turbine’s back-end steam can be sold for distribution to district heating systems. In situations where the same utility controls both markets, overall ease of system implementation is generally further increased.” [4]

Many places where resource recovery systems have been installed in the United States and Europe, the outcome has been positive, providing a new source of economical energy, relieving the waste disposal problem, reducing dependence on fossil fuels, and giving each community a permanent source of energy immune to the threats of depletion that hound the footsteps of the main conventional fuels. As with any new energy development, serious problems have hampered some operations, requiring costly repairs or design changes. However, the long-range prospect for energy from waste is favorable.
SHOULD YOU RETROFIT YOUR UTILITY?

A general "yes" or "no" answer to this question is not possible, because each situation is different and must be decided on its own merits. In many cases, the best answer seems to be that it is better to retrofit, despite problems, than not to cogenerate at all.

A New York State study in 1977 favored retrofitting power plants and users to harvest the benefits of cogeneration and district heating. The argument was made that it costs too much in energy wasted to wait the ten years it normally takes to build new electric generating facilities. Retrofitting can be accomplished faster and energy saved. [3]

With the growth pattern of electrical consumption slowing through conservation and efficiency, utilities may find it helpful to encourage electric generation by industry, small power suppliers, and others, such as small hydro developers, who can help meet electrical needs in regions without new large-scale power plants. Using this approach, plans for new plant construction were put aside by Southern California Edison.

Since fewer new plants will be needed, retrofitting is the prime option in the United States. Thus, the U.S. will not be able to follow the successful European approach to an optimum extent. In Europe the practice has been to install district heating networks simultaneously with new building construction. In Sweden, temporary boilers are used in new neighborhoods to serve customers until the need is sufficient to support the building of a new cogeneration facility.

This is the most efficient way to implement district heating systems, and the approach should be used wherever possible in the United States. However, the drawback in the United States is that "at the present time . . . new building construction is at a low level relative to existing building volume." [3]

As previously noted, Europe benefited from the massive rebuilding required following World War II to introduce district heating and gain experience in its implementation. Some Amer-
ican cities battered by economic wars during the 1960s and 1970s might benefit from rebuilding, but this is likely to occur—when it occurs—piecemeal and erratically. Thus, the process of building, in effect, new cities with new district heating systems will not take place in the United States to any significant extent. Retrofitting, however, provides a way to introduce cogeneration and district heating effectively some places where existing facilities, buildings, and business or residential clusters supply appropriate conditions.

**BENEFITS IN MULTIPLE DIRECTIONS**

Canadian humorist Stephen Leacock wrote about the impetuous hero who “flung himself from the room, flung himself upon his horse and rode madly off in all directions.”

The benefits of cogeneration and district heating do not take off in all directions, but they are inclined to gallop off in more directions than might be readily noticed.

- Less risk of fire from storing fuels in buildings. District heating brings steam or hot water in. The fuel is burned elsewhere.
- Maintenance of heating and cooling equipment is greatly simplified, which also means lower maintenance costs.
- Space is saved in buildings which no longer need individual boilers and furnaces.
- Traffic at sea and on land is reduced for delivery of fuel.
- Snow melts above district heating pipes which lessens the problem of snow and the cost of its removal.
- Constructing district heating systems means jobs in economically depressed urban areas.

The list might be continued to contain the environmental benefits, the ability to use alternate fuels, the reduced pressure on conventional fuels, the savings in energy and the savings in money, protection against fuel shortages in the critical matter of winter heating.
But a comprehensive list of benefits need not be repeated here. It has been compiled and stated with facts and arguments in preceding chapters. Parisi’s April 1981 observation provides an apt summation that implies benefits, expresses optimism, and qualifies the whole with a cautious “maybe”: “In the minds of many, the sensible economics of cogeneration is sooner or later going to prevail.” [1]

The question is whether or not those particular minds will prevail in setting and implementing United States energy policy, posture, and direction.

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Cogeneration, District Heating, and the Future

It's so incredibly impressive when you look back at our planet from out there in space and you realize so forcibly that it's a closed system—that we don't have any unlimited resources, that there's only so much air and so much water. You get out there in space and you say to yourself, "That's home. That's the only home we have, and the only home we're going to have for a long time."

Edgar Dean Mitchell
Apollo 14 Astronaut

STARTING FROM WHERE WE ARE

District heating is four years into its second century, yet the major potential for this technology is still in the future, especially in the United States. Cogeneration parallels much of the history and also much of the neglect shown to the district heating opportunity, again especially in the United States.

Neglect has not characterized development elsewhere. After World War II, Europe invested steadily and heavily in district heating. Hot water systems, because of technical superiority, were developed widely. The result of this foresight rewards Europeans today in many countries with more economical and reliable thermal energy than they could have in the absence of district heating and cogeneration.
Why has the U.S. been slow to move in this area? There is no great mystery. For district heating, the profits weren’t there, and the price wasn’t right. For cogeneration, there was little incentive with fuel cheap and no recognized need to conserve it.

Heavy use of cheap fuel inevitably took its toll in this “closed system” that Astronaut Mitchell wrote about. Today natural gas and oil are still the primary sources of space conditioning and domestic hot water, but reserves of both fuels are now down to a few more decades of use worldwide. This makes energy conservation and the use of alternate fuels a critical future obligation for the United States and the world. The time of rhetoric is rapidly fading, and the time of action becomes imperative. Cogeneration and district heating are prominent avenues for beneficial action.

One lesson we have learned from the recent past is that we can’t afford artificial supports to keep prices low on finite energy sources. Low-cost oil and gas, with prices that did not equal their value, simply encouraged energy waste and hastened the depletion of these fossil fuels. The facts are starkly manifest that distressingly little energy conservation takes place because it is nationally needed or morally right. It takes place because expense can be reduced enough to achieve important and necessary savings.

In that respect, cogeneration and district heating meet future specifications. When the potential benefits of this technology are considered, it seems regrettable that the United States, unlike Europe, didn’t start sooner. But then no merit is gained in crying over spilt steam, and there is consolation in the fact that it isn’t too late to begin. The distinctive features of the technology have always been available, however, these features will be more important in the future than they were in the past.

**USE ANY FUEL YOU FIND**

Cogeneration plants can be designed to operate on alternate fuels impossible or impractical to consider in homes, buildings,
and even industries. Nuclear fission, for example, is never likely to be individually adapted to the residential market. Even if it became technologically manageable, would many homeowners, especially with small kids and pets, really want the responsibility of a nuclear reactor in the basement.

Nuclear cogeneration, cogeneration using coal, municipal refuse, sewage sludge, solar energy, geothermal energy, peat, etc., are realistically possible, even probable. Plants to generate electricity from burning wood are projected for the United States. Cogeneration could make such plants more efficient if they deliver district heating service as well as electricity.

Substituting alternate fuels for oil and gas in areas where cogeneration efficiency is practical represents energy adaptability that will be essential in coming years. There is no other realistic way available to conserve oil and gas as long as possible for use in low-density population areas where district heating developments will not be practical.

CLEAN THE WIND, WASH THE RIVERS

Poet Samuel Taylor Coleridge asked an important modern question early in the 19th century:

The river Rhine, it is well known,
Doth wash your city of Cologne;
But tell me, nymphs! what power divine
Shall henceforth wash the river Rhine?

Cogeneration and district heating systems in Europe help wash the rivers, cities, earth, and air by significantly reducing heating system emissions. Environmental benefits are major considerations, particularly for large cities now waging perpetual war with pollution.

Cogeneration by utilities and industries will utilize thermal energy that otherwise would be discarded into the atmosphere and rivers. The energy efficiency of cogeneration also results in less fuel being used to accomplish the same end. This limits further the total amount of residue from fuel combustion.
District heating is no less a friend of a cleaner environment. To supply hot water or steam for district heating pipes, fuel—whatever is available—is burned at the central plant where appropriate effluent controls and exhaust clean-up equipment can be efficiently maintained. District heating operations in Europe are conspicuous because of the towering flue stacks on plants, designed to broadcast emissions over broad areas, away from population clusters.

MORE ENERGY FOR LESS MONEY

Cogeneration and district heating economies become more appealing as energy prices rise. The oil embargo in the mid-1970s started the process of shocking Americans awake to new energy realities. The country at that point had long broken Rip Van Winkle’s record by sleeping much more than 20 years. The waking process continued through the 1970s and into the 1980s. Whatever time is required for eyes to open and vision to clear, eventually the fuel efficiency of cogeneration and district heating will have to be noticed.

**Figure 12-1. Cogeneration versatility and efficiency.** To cogenerate or not to cogenerate is a choice between 80% energy-efficiency and 33% efficiency. Other factors affect energy decisions, of course. Based on efficient energy return from fuel burned alone, cogeneration has a marked advantage.
Fuel efficiency allows district heating systems to pay for themselves. In most cities, district heating can serve to stabilize heating costs for low-income families in multiple-family dwellings. These are the people hardest hit by blunt collision with higher heating costs. District heating in such areas will lessen the need for endless fuel subsidies.

District heating projects will have another economic dividend welcome in cities such as Detroit, Philadelphia, and New York with the chronic problem of unemployment: District heating will mean jobs. Employment opportunities during the construction phase will continue several years.

Controlled prices, greater efficiency, jobs . . . these are objectives this energy technology can help achieve, when energy foresight catches up with energy need.

TECHNOLOGY OF THE FUTURE

Cogeneration and district heating will stimulate and assist in bringing about the switch to alternate energy forms. They should also contribute to technological advances in the safe burning of coal, solid waste, biomass, and other alternates waiting in the wings to take their turns at center stage when oil and gas begin wrapping up their act. Cogeneration and district heating adapt so readily to new energy forms, such options as geothermal, nuclear, and solar are likely to be associated in the early stages of their development with cogeneration applications. Seasonal thermal energy storage in underground aquifers is a little-known option that will gain more attention as a result of the nation’s trend.

In connection with nuclear cogeneration, the national strategy in 1980 emphasized that “increased attention will be given to assessing the application of nuclear energy for district heating and cooling so that data will be available regarding technical and economic feasibility. . . . This assessment would not examine the technical design of the reactor itself, but would stress increased effective utilization of thermal energy from nuclear plants, as well as changes in the nuclear system that
would be required in order to supply the heat to the community and industry safely and economically.” [1]

Cogeneration technology will benefit from improved techniques in nonnuclear fields as well. Some predictions are that cogeneration technology before the end of the century will quadruple the energy savings potential of existing systems. Among the advances identified by the U.S. Department of Energy are new turbine-cooling methods, low-emission combustors, and ceramic protective coatings. These will enable gas turbines to operate at higher temperatures and with residual oils or coal-derived liquids that require minimal processing. [2]

“Future prospects for cogeneration are excellent, and even currently available systems are cost-competitive with conventional electric utility systems,” the Department of Energy reported in 1978. [2]

PROSPECTS OR PROMISES?

There is no guarantee that what should happen will happen with cogeneration. The need is pronounced for the benefits promised by this technology, but the obstacles—political, institutional, social, financial—will not be easy or inexpensive to overcome. Where there’s a will there’s a way, but where there’s a need there isn’t always the will.

Reducing future energy demand through energy efficiency and fuel substitution has high priority in U.S. energy policy. “District heating and cooling has the potential to play a significant role in accomplishing this goal for the United States, thereby increasing our national security and improving our balance-of-payments status.” [1]

Translating potential into promises kept is the work ahead for cogeneration and district heating technology in the United States. Table 12-1 illustrates the extent of the district heating promise to be fulfilled by the United States in comparison with representative European countries.
Table 12-1. Installed District Heating Capacity [3]

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Installed Capacity (MW)</th>
<th>Population (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>1975</td>
<td>7,400</td>
<td>215</td>
</tr>
<tr>
<td>West Germany</td>
<td>1975</td>
<td>23,400</td>
<td>62</td>
</tr>
<tr>
<td>Sweden</td>
<td>1979</td>
<td>12,000</td>
<td>8</td>
</tr>
<tr>
<td>(Projected to)</td>
<td>2000</td>
<td>30,000</td>
<td>8</td>
</tr>
<tr>
<td>Denmark</td>
<td>1975</td>
<td>10,000</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>1973</td>
<td>5,200</td>
<td>52</td>
</tr>
<tr>
<td>U.S.S.R.</td>
<td>1975</td>
<td>494,000</td>
<td>246</td>
</tr>
<tr>
<td>Finland</td>
<td>1977</td>
<td>4,900</td>
<td>5</td>
</tr>
</tbody>
</table>

These figures say something about national interest in energy conservation and efficiency. What message will updated tables in 1985, 1990, 2000 deliver on the same topic? Each country in this table except one is vigorously expanding current district heating activity and seeking new ways to cogenerate heat and electricity more efficiently.

Cogeneration and district heating technology is available to any county, state, community, industry, shopping center, university, medical center, housing complex, or utility that might be interested.

In the United States various individuals associated with such activities have shown considerable interest and some have gone considerably farther to build total energy plants, organize community groups to serve as advocates for district heating developments, or find useful ways to save waste industrial heat as in the case of Bellingham, Washington and Intalco aluminum processing plant.

Other cogeneration/district heating opportunities will be found and acted on in the United States by individuals with their eyes open and realization that energy commonsense begins at home not necessarily in the state capital or in Washington.
DECISIONS AND DECISIONMAKERS

As with all progress, no doubt committed individuals finally must make this waiting and pragmatic technology work for America. If governments must be moved, individuals will move them. They will be the achievers, the movers, and the shakers who will use district heating and other environmentally benign, energy-responsible technologies to help accomplish what poet T. S. Eliot identified as a human priority nearly half a century ago:

Clean the air! clean the sky! wash the wind! take stone
from stone and wash them.
The land is foul, the water is foul . . .
It is not we alone, it is not the house, it is not the city
that is defiled,
But the world that is wholly foul.
Clean the air! clean the sky! wash the wind!

In these poetic undertakings, cogeneration and district heating do not abolish pollution from the earth by themselves. But they contribute, they make improvements. Alone they will not end concerns about energy. But they do conserve. They help stretch existing supplies realistically and do so without negative environmental side effects. They help with the worsening problem of high energy prices. When the need is great, any assistance is welcome. Birdsill Holly’s brainchild can supply expert assistance, perform a remarkably dependable job, and keep millions of Americans warm through cold winters ahead. Cogeneration, by consuming frugally whatever fuel is available, will help Americans buy time to prepare cautiously for a future without the late lamented fossil fuels.

Dr. Franklin at a learned table in Paris answered the question, “What description of men most deserves pity?” by saying, “A lonesome man in a rainy day, who does not know how to read.” [5] The near twin of that pitiable man in the year 2000 will be a cold man in a wintry day who does not yet know
how to heat his home with a little fuel from a central source. Looking back in 20 years, some will be glad they acted, others will wish they had.

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