DISTRICT HEATING WITH COAL

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A recent article[1] called attention in an arresting manner to a fact of high significance in conservation: namely, that though the total energy resources of the United States are tremendous, coal constitutes 98.8 percent of our total known fossil fuel energy reserves. Moreover, our oil and natural gas reserves are being depleted at an astonishing and, what is even more significant, a constantly increasing rate.

It is an axiom of conservation that when no disturbing factor is present, the substitution of an abundant resource for one in short supply is a strongly conservative measure.

Unfortunately, in dealing with the conservation of nonrenewable resources, though the depletion problem is clearly recognized, too often the sole remedy suggested is restraint in the use of the resource. This paper discusses a highly rewarding measure looking toward the conservation of our energy resources —district heating. It is a matter requiring careful consideration by all interested in resource conservation and urban planning because, under favorable circumstances, it can make significant contributions toward the solution of an amazing variety of problems in these two fields. Moreover, it is a technique which is not widely appreciated and understood.

District heating refers to the heating of several buildings or even several hundred buildings from one heating plant instead of by an individual combustion installation in each building. It is sometimes referred to as central heating, but because this latter term is often used to distinguish between the heating of one building from a single source of heat and the heating by units located in individual rooms, the term district heating seems preferable.

Steam or hot water is produced at one large central station and distributed by underground pipes to the individual buildings. The building owners pay for the steam either at a flat rate, by the amount of steam used as measured by a meter, or by other types of rate arrangements. Where large amounts of water are available, air conditioning is possible from central steam plants. It is a public utility.

Under appropriate circumstances it is as sound an investment from an economic viewpoint as is any other public utility. Moreover, if it were completely developed it would dwarf any other public utility in size. One need only compare his annual expenditures for gas, electricity, or water with his annual

[1] E. Willard Miller, "Mineral Fuel Situation in the United States," *Jour. Geog.* Vol. XLVIII, Nov. 1949, p 318.

expenditures for heating his home to check the validity of the foregoing statement.

Practically no concrete figures are available to show the financial aspects of a district heating unit. This is true for a variety of reasons. The two most important are: (1) almost all district heating companies in the United States are primarily in the electric generating business, and steam for heating is a subsidiary, byproduct enterprise. Hence cost figures and profits statements are uninformative, and (2) the enormous technological improvements (especially in the construction of distribution mains) during the last 15 years have greatly increased the efficiency and profitableness of large steam distribution systems. Despite the dearth of direct financial evidence, there is no doubt of the economic feasibility of the technique.[2] Moreover the industry is more widespread than is generally realized.

District Heating Industry

District heating is not a new development. The sale of steam as a commercial enterprise began in 1879 at Lockport, New York.[3] The industry has been growing slowly ever since. Nor is it confined to the United States, though the technique is confined to the major industrial nations. The three leading nations in the industry are the United States, Germany, and the Soviet Union. There are smaller developments of district heating in Belgium, The Netherlands, and France, and a few isolated developments in other European nations and the British Isles.

Some foreign developments.—Paris has a major district heating system. From the time of its inception until 1938 it expanded steadily, by which time the mains reached as far as four and a half miles from the heating plant. No attempt was made to integrate the heating system with the production of electric power because the main steam load occurs in the morning and the principal electrical demand is in late afternoon.[4] A larger project for the future envisions supplying heat to the entire city from three electric plants already in existence, located at the points of a triangle about eight miles apart.

Some of the largest, oldest, and best-integrated district heating systems in the world are located in Germany. District heating systems are found in Berlin, Chemnitz, Karlsbad, Karlsruhe, Beelitz, Heidelberg, and Stettin. In some cases they are integrated with electric generating plants, in others with the production of steam for power, and with large-scale industrial developments exploiting low-grade lignite deposits. Other European cities with similar systems are Vienna, Oslo, Zurich, Lausanne, and Copenhagen.

District heating in Russia began shortly after the founding of the Soviet regime. Just before the war the Soviet Government was pushing the program of expansion vigorously. The earliest Soviet district heating plant was converted from an old

[2] Anyone interested in pursuing further the economics of district heating will find detailed discussions in: Roger De Wolf, "An Economic Analysis of Central Heating," *American City*, Sept. 1946, p. 131; R. L. Fitzgerald, "Central Steam Heating—a Post-War Reality?" *American City*, May 1945. p. 109.

[3] "Central Heating," *Business Week*, March 17, 1945, p. 42.

[4] P. Serechewsky, "District Heating in Paris," *Proceed. National District Heating Assoc.*, 1943, pp. 20-22.

Leningrad power station in 1924. This worked out so successfully that other plans were immediately initiated. The early district heating stations were constructed largely to supply heat to factories, but eventually the service was extended to the adjacent workers' settlements. The predominant heating medium in the Soviet Union is hot water.[5] As the development progressed the heating plants carried on byproduct power generation. They became, in fact, public utility stations supplying the adjacent areas with heat, power, and hot water.

Economic considerations as usually conceived were not always the primary consideration in the building of the plants. Many of the plants were established in the north and east in order that low-grade local fuel and even peat might be burned as extensively as possible in order to lessen the drain on the higher-grade coal production from southern Russia, and also to lessen the strain on the transportation system of the long rail hauls from the Donbas and other more remote coal fields. The accompanying table indicates the rapid extension of the service.

Growth of District Heating in the Soviet Union[6]

	1929	1933	1939
No. of plants..........	14	53	106
Heat output per year (Billions of Btu)		218	874
Electric capacity (Million kilowatts)..	.56	5.3	17.5

Certain local conditions have materially aided the successful operation of the Soviet plants. The winters are long and cold, and a high proportion of the heat is furnished to factories. Both these factors insure a steady and long-continuing demand. Moreover the Russians have the advantage of being able to bring all space in the area under the heat load of a single station. Finally, slight modifications to bring the heat and power load into close conformance are quite possible.

It is highly significant to note, with regard to the feasibility of district heating, that the plan for the rebuilding of the central portion of Rotterdam calls for a complete district heating system. There is to be one main plant and two substations. The two substations will be for supplementary service during periods of very low temperatures and will also perform standby functions. The heating medium is to be hot water. It is estimated that there will be substantial savings in construction materials and a coal saving of 28,000 tons annually.[7]

Though district heating systems have been very small in Britain in the past, interest in a widespread extension is very great. A thorough investigation of the matter has been undertaken by a government committee and their report is an excellent short discussion of the subject.[8]

District heating in the United States. — The United States has about 200 district heating systems selling to the public. There are approximately 1,200 systems privately operated or selling to some closed organization of customers.[9] A set of college buildings all heated from

[5] "District Heating in Russia," *Heating and Ventilating*, March 1944, p. 82. A report of an address by Mr. Paul G. Kaufman before the Royal Netherlands Institute of Engineers.

[6] *Ibid.*

[7] M. C. Hoenkamp, "Stadsverwarming Rotterdam," *Bouw Rotterdam*, May 1947, pp. 31-33.

[8] *Interim Memorandum on District Heating*, Department of Scientific and Industrial Research, London. His Majesty's Stationery Office, 1946.

[9] R. De Wolf, *op. cit.*

a central station would be an example of the latter.

The largest district heating system in the United States is that of the New York Steam Corporation. It is a subsidiary of the Consolidated Edison Company—an electric utility. The tremendous size of the system may be judged from the fact that it serves about 16 percent of the heating requirements of the entire city of New York. Its market is Manhattan Island, with the greatest per-acre heating requirements in the world. Despite this enormous space-heating business, the sale of steam is only an ancillary operation to the principal business of the parent company—electric power generation. This is a characteristic of almost every district heating system in the United States. They are not primarily in the steam business; they are in the electrical business.[10]

Other large district heating systems are located in Detroit, Cleveland, Chicago, and such smaller cities as Akron, Youngstown, Indianapolis, and Rochester, New York. Lansing, Michigan, is the largest city in the United States with a municipal steam utility.

The Detroit system is an adequate example. It serves an area three and a half miles long by one-half to two miles wide in downtown Detroit. It has approximately 1,600 customers. The structures include office buildings, restaurants, factories, department stores, hotels, apartments, rooming houses, and residences.[11]

An excellent example of a smaller district heating system is that of the Parkchester apartment housing group in New York. The system furnishes all domestic hot water and heat to the 35,000 residents and all the connected commercial establishments with a total annual coal consumption of 35,000 tons.[12] The coal is all delivered at one point by railway hopper cars, and the ashes are hauled away by truck after being thoroughly wetted down and loaded entirely by machinery. Compare this with ordinary methods of coal delivery and ash removal! Some notion of fuel savings effected by district heating of compact units may be had by comparing Parkchester's consumption of one ton of coal per year per person with the consumption per capita of individually fired furnaces in the latitude of New York.

The district heating system at Virginia, Minnesota, is one of the most interesting and instructive. It is the only city in the nation having a municipal heating plant serving the entire population. It is operated as a nonprofit enterprise. The steam is produced to generate electricity and then fed into the heating system. Despite the low per-acre heat requirements and the fact that the majority of the units are individual dwellings, the cost of the service to the consumer is only half the cost of heating a dwelling on an individual basis.[13] It seems to indicate clearly that in the colder sections of the country a tremendous expansion of the district heating technique is eminently feasible.

[10] *Ibid.*

[11] G. D. Winans, "District Heating in Detroit," *Heating and Ventilating*, Nov. 1946, p. 64.

[12] T. J. Moffett, "Parkchester Converts to Coal," *Heating and Ventilating*, Nov. 1946, p. 64.

[13] "Municipal Central Heating System Serves Whole City," *Engineering News Record*, Dec. 28, 1944, p. 79.

Value to the Individual Property Owner

The extent of the gains made by the individual property owner by a change from unit heating to district heating depends in part on the type of heating equipment presently installed, and in part on the size of the structure he owns. Certain gains, however, accrue to all property owners.

There is a considerable increase in the reliability of the heat supply. This is a matter of major importance for commercial building owners and also for the residential property owner during any period when he may be absent.

Net available space is increased in all buildings served by a central heating station, because no space is required for an individual heating unit. Insofar as this gain in space is of any importance, it has a stimulating effect on the construction industry because that industry can furnish a larger amount of available space for the same price. In residences with small, compact oil or gas heating units the space savings will be small; but in buildings or residences with coal-fired furnaces with a large bin for coal storage the net gain may reach as high as a third of the total cubic contents of the house.

Regardless of the type of structure or the type of individual heating unit used, the fire hazard is materially lessened by district heating. Where district heating is widespread, insurance rates are considerably lower.

All furnace labor is done away with.

It will be noted from the above discussion that most of the advantages of district heating as contrasted with the coal-fired furnace can also be gained by installing gas or oil heating units in a house. The advantages and disadvantages of this procedure are thoroughly understood by everyone. It is important, however, to point out here that these disadvantages can be more thoroughly and completely overcome by a change to district heating.

Value to City Planning and Management

The control of atmospheric pollution is a problem with which urban officials and city planners have long been wrestling. Hundreds of thousands of poorly managed, low-temperature fires in individual heating units make large contributions to the atmospheric pollution in any city throughout the cold season. By eliminating all these individual heating units and concentrating them in one large plant where the fires can be efficiently handled and where elaborate and expensive devices for the complete control of smoke and gases are possible reduces this source of atmospheric pollution to negligible size. It would serve as a major contribution to the health of the population, to a decrease in cleaning bills and expenditures for soap, to a reduction in the cost of cleaning and painting buildings, and would increase the general pleasantness of the city.

The concentration of heat-generating processes into a single plant greatly reduces the fire hazards in a city. A study made by the National Board of Fire Underwriters indicates that over a fourth of all property losses from fire are attributable to faulty local heating facilities.[14]

The concentration of ashes at one station greatly reduces the cost of removing them. A district heating plant commonly loads its ashes by gravity from a hopper directly into a truck. Such a system greatly reduces the cost of removing ashes as well as keeping dust and dirt to a minimum. The added gain in cleanliness of a city that would result from the concentration of all coal deliveries at a single station does not need to be described.

Finally, in areas of traffic congestion district heating would somewhat reduce the local traffic load by removing the slow-moving vehicles delivering coal or hauling ashes.

Value for Resource Conservation and Management

Past experience in the United States would indicate that total fuel requirements for heating do not appear to be greatly lowered by a change from individual heating units to district heating. But the steady advance of heating technology may have changed this situation; recent studies seem to indicate rather considerable fuel savings from district heating. To a considerable extent it is dependent on the per-acre heat requirements, because the large thermal losses are in the distribution system. In theory the savings should be large. It is estimated that only a small proportion of all individual heating units are operated at more than 50 percent fuel efficiency, whereas large, competently managed district heating plants easily obtain about 85 percent fuel efficiency.

If all individual heating units were fired with coal the net savings might be zero; but for two decades there has been a steady and powerful swing away from coal toward natural gas and petroleum as a source of heat. The fuel-consuming public intends to be free of the atmospheric pollution, dirt, ashes, and furnace labor that accompany the coal furnace. Consequently, consumption of fuel oil and natural gas for home and commercial heating has been steadily cutting into the market for coal. Few people are sufficiently aware of the magnitude of this change. One small example may indicate the trend. In 1945, over 6,000 new heating installations were made in the cities of Minneapolis and St. Paul. New coal-burning installations represented only 7.8 percent of this total. This trend seems certain to continue; more and more of our total heating requirements are going to be met by oil and gas consumption.

The significance for fuel conservation of district heating does not lie in the lowering of total fuel consumption; but rather in the fact that district heating accomplishes more successfully everything that is gained by switching to oil or gas heat, and simultaneously substitutes an abundant fuel, coal, for the higher-value, scarcer fuels—natural gas and petroleum.

Certain other general public advantages would accrue also. Except during wartime, the bituminous coal industry has been in poor condition for over two decades, and its posi-

[14] *Business Week, loc. cit.*

tion has been deteriorating steadily. The industry is overexpanded, and at the same time its share in the national fuel market has been steadily dwindling. It has been desperately looking for new markets for its products. A great expansion of coal-burning district heating plants would provide a new multimillion-ton market for bituminous coal.

Another point of concern has been the serious loss of railroad revenue as their coal tonnages have declined coincident with the drop in coal consumption. A large increase in coal consumption by district heating plants would, of course, greatly increase the revenues from coal transportation by rail.

The construction of a district heating plant requires large capital expenditures. Following a drop in the level of business activity, a noteworthy outlet for investment funds and a major source of employment for the equipment and personnel of the construction industry would be furnished by a widespread change from unit heating to district heating.

Major Limitations of District Heating Systems

Wherever annual heat requirements are low the economic and practical values of district heating dwindle. It is obviously unnecessary to create an expensive and elaborate heating system with all its high interest and amortization charges to service buildings in a community for only a small part of the year. Heat requirements have to be high throughout a considerable portion of the year in order to make district heating economical. The pertinent term here is "load factor." The load factor expresses the relationship between the maximum demands on the heating system and the average demand. It is expressed as a percentage. It is analogous with the load factor in electrical demand or the sale of natural gas. The higher the load factor the greater the probability of successful operation. Long months of steady demand on a heating system are necessary to the economical operation of the district heating unit. One writer has summarized the situation by saying that the executives of commercial district heating firms pray for cold weather like a small boy with a new pair of skates for Christmas.

Various isotherms and degree-day lines have been proposed as marking the climatic limits of eonomical operation of a district heating system. Keeping in mind the distribution of population in the United States, it seems clear that with present methods the northeast quarter of the United States represents the area of greatest potential and economically most feasible development.[15]

But at this point it is necessary to remind ourselves of the possibility of district air conditioning. One large manufacturer of heating and ventilating equipment has made an economic analysis which indicates that air conditioning from central stations is entirely feasible, at least for some types of building arrangements. No plant has ever actually operated to demonstrate the accuracy of their analysis. For an apartment house group it was estimated that two-story apartment houses in

[15] District heating systems are operating successfully as far south as Atlanta, Georgia.

New York could be cooled half the time for a cost of $1.27 per room per month.[16]

One can easily visualize a situation where the air conditioning service would be the major enterprise and heating the subsidiary activity. It must be reemphasized that to do this with a steam plant requires large amounts of water. Developments along the line of dual-function district heating and cooling plants need to be watched closely in the future by anyone interested in fuel conservation and urban problems.

A second major limitation to be considered with regard to the feasibility of installing a district heating system is the cost of converting buildings heated by some other method to steam or hot water. With new buildings or with buildings heated by steam this is no problem, but conversion costs for private dwellings heated by some other method will run from $300 to $1,000 per unit. Many property owners will be unwilling to shoulder this initial cost.

Another possible source of difficulty is obsolescence of the district heating equipment by changes in heating technology. Recent developments in radiant heating, heat pumps, and solar heating are suggestive of the possibilities here.

Dependence for heat on a commercial source adds one more item to the list of fixed costs of owning a dwelling. This is a matter of some concern to housing authorities. The British investigation took special cognizance of this problem.[17]

Finally, district heating is not feasible in an area of scattered homes. At least a moderately compact development is a prerequisite for economical district heating.

[16] "Central Heating and Air Conditioning for Apartment Housing Development," *Heating and Ventilating*, Oct. 1945, p. 116.

[17] *Interim Memorandum* on District Heating, Department of Scientific and Industrial Research, London. His Majesty's Stationery Office, 1946.