DISTRICT HEATING

IDHA BULLETIN

★ ★ ★ SPECIAL CONFERENCE EDITION ★ ★ ★

June 14, 1982

Canadian District Heating is Focus at Quebec Meeting

2ND QUARTER 1982 VOL. 67 NO. 4

Potential Opportunities for Revitalizing A Steam District Heating System: A Case Study of Rochester, New York*

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ABSTRACT

The Rochester district heating system is typical of many other district heating systems in the country. Changing urban patterns and unprecedented fuel price increases have combined to make many systems unprofitable or to earn a relatively low rate of return. In the case of Rochester, the immediate problem is to reduce the system's dependence upon oil and to seek opportunities for increasing the number of customers.

Three options were proposed for sustaining and improving the Rochester steam district heating system. The first option investigated conversion of an existing coal-fired turbine to cogeneration. The second considered use of refuse-derived fuel and modular incineration with heat recovery to provide the district heating system with steam. These two options are near term approaches to reduce the system's dependence upon oil and to lower the cost of delivered steam. The third option proposes a long range strategy to develop hot water heat islands adjacent to the center city area. Development of a successful hot water heat island would represent the first growth node of a major new district heating system in Rochester.

INTRODUCTION

Eight years have elapsed since the 1973 Arab oil embargo. During this period, the nation has been repeatedly subjected to a series of energy related aftershocks. Fuel shortages, escalating prices, and unstable energy markets have contributed to the general perception of an uncertain economic future.

Many different strategies have been pursued to counteract the disruptions. Conservation has been the primary pathway chosen by many elements in the public and private sectors. Improved building insulation, thermostat controls, fuel substitutions, and more efficient means of transportation were the major components. The industrial sector relied upon a range of conservation, management, and redesign options to modify energy consumption. Government employed a combination of tax incentives, grants, regulation, research, and education programs to alter national energy use patterns.

Numerous strategies designed to alleviate energy problems have contributed to an increased awareness of the fundamental role that energy plays in the orderly functioning of society. With additional experience and sophistication has come the recognition that current practices provide only limited solutions to the national energy situation. Many of the simple and expedient solutions are in the initial phases of market penetration and other more complex opportunities will require comprehensive involvement at both the national and local levels. District heating is one of the opportunities that fits in the latter category and has the potential of providing urban buildings with a reliable domestic energy source.

The Department of Housing and Urban Development (HUD) views district heating as a useful tool for revitalizing many distressed urban areas. HUD therefore instructed the Oak Ridge National Laboratory to provide direct assistance to cities and utilities that were interested in rescuing their existing district systems. Demonstrating viability of existing systems was deemed necessary to establish credibility and overcome general misconceptions about the potential role of district heating in this country.

The city of Rochester, New York was among the first communities to request assistance from HUD.

ROCHESTER DISTRICT HEATING SYSTEM

The district heating story in Rochester began in the year 1889. The steam system was the outgrowth of Rochester Gas & Electric Corporation's (RG&E) desire to sell electricity in the downtown area.[1] Many of RG&E's prospective electric customers were already producing their own electricity on site with small coal-fired steam turbines. The exhaust steam from the turbines was used to heat buildings and provide process heat. Purchasing electricity from the utility would require building owners to abandon their own facilities and seek alternative sources of space heat and process steam. To promote electrical

*Research sponsored by the Office of Policy Development and Research U.S. Department of Housing and Urban Development under Interagency Agreement IAA-H-40-72 DOE 40-333-72 under Union Carbide Corporation contract W-7405-eng-26 with the U.S. Department of Energy.

sales, RG&E offered to deliver steam to their initial electric customers. The steam system grew in conjunction with the electrical service and became the desired service for new buildings in downtown Rochester.

In 1963, the system was the fourth largest in the U.S. with a peak send-out of 390 MW(t) [1.40 TH/hr]. The system served 621 customers and was growing steadily. From 1963 to 1979, there was a loss of about 320 customers and the system's peak send-out was reduced to 275 MW(t) [1.0TJ/hr]. Customer loss resulted from a massive urban renewal program and the rising price of steam. Urban renewal removed many steam-served buildings which have not been rebuilt. However, the increased cost of steam was due primarily to the rapid escalation in oil prices (the system's prime fuel).

Urban renewal was perceived by both the city and RG&E as mutually beneficial. The intent of renewal was to remove slums and other blighted properties in the city and to reorganize vacant lands in a manner more consistent with anticipated future needs. The city's goal was to replace numerous antiquated, low-level buildings with fewer and more modern multi-story commercial structures. The district heating business also expected to benefit from the renewal program. Although steam sales were expected to decline during the demolition phase, overall sales were projected to increase as the downtown area redeveloped. The building demolition phase is now complete, but the city has only partially succeeded in developing new multi-story buildings in the downtown area. The lack of anticipated commercial redevelopment has prevented the steam system from attaining its former level of sales. Operating well below capacity, the system continues to be a marginal business.
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The second major event that contributed to the decline of the steam system was RG&E's decision in the early 1970's to convert existing coal-fired boilers to natural gas and oil. Conversion was in response to federal air quality and emission regulations. Shortly after conversion, the country was confronted with the 1973 Arab oil embargo. The cost of oil escalated from approximately \$ .80/10^6 Btu (\$ .76/GJ) to a recent high of approximately \$3.60/10^6 Btu (\$3.40/GJ). The price of delivered steam is now more than the price of natural gas in Rochester. Faced with the prospect of ever increasing steam costs, many district heating customers have converted to natural gas.

In summary, two problems must be addressed to assure the long-term viability of the district heating system. The most immediate problem is the necessity to convert from oil and natural gas to a less expensive fuel to stabilize or reduce steam costs. This price should result in the return of many former customers. The second major problem is a question of increasing the number of customers. The initial impact of urban renewal has had a major adverse effect upon the steam business and the system remains only marginally viable. If the trend in customer loss and decreased sales cannot be offset, it is unlikely that the system will remain active.

STEAM STATIONS AND DISTRIBUTION SYSTEMS

The RG&E district heating business is composed of two separate but interconnected franchise areas, the Downtown and Industrial District systems (Fig. 1). The Downtown system, where the steam business began, now serves predominantly commercial space heating and hot water loads. At present, 275 customers are connected to the Downtown system with a total sales (in 1979) of 1.71 x 10^9 lb/yr (1.8 PJ/yr). Steam is supplied to the area from two stations. The oldest station, Station #8, originally served as a cogeneration facility but today is used to supply supplemental steam for winter peak days.[2] The primary facility, Station #3, is a cogeneration plant that supplies steam from two topping turbines. Station #3 has a common high pressure header of 660 psig and employs three main modes of operation: (1) 660 psig [4652 kPa] steam is supplied to the turbines and exhausted at 200 psig [1480 kPa] to the district system, (2) 660 psig [4652 kPa] steam is fed into part of the system to meet peak heating demands, and (3) all steam is dedicated to electrical production.

The Industrial District system (referred to as Station #9) is located on the west side of the city. This system was formed in the mid-twenties to supply high pressure steam for proposed industrial expansion. It currently serves approximately 25 industrial customers with total annual sales (in 1979) of 1.08 x 10^9 lb/yr (1.14 PJ/yr). Station #9, the central steam source for the district, is fueled by natural gas. The station contains only one small topping turbine that exhausts 15 psig (203 kPa), low-pressure steam. Steam is distributed from the station at one of three pressures; either 15, 180 or 335 psig (203, 1342, or 2411 kPa). For all practical purposes, Station #9 functions as a heat-only plant.

OPTIONS FOR REVITALIZING THE STEAM SYSTEM

Three options have been proposed to demonstrate the range of potential alternatives available for sustaining and improving the Rochester district heating system. Two near-term options have been developed to reduce the steam system's dependence upon oil. The third option represents a long-range strategy to develop hot water heat islands adjacent to the Downtown system. All three options indicate a potential for large scale fuel savings. No attempt has been made to conduct a rigorous economic analysis of the proposed options. It is recognized, however, that before a final evaluation of any option, a thorough economic analysis must be performed.

Unit #12 Conversion

The first option considered conversion of the coal-fired Unit #12 of the Downtown system to cogeneration. Although physically located in Station #3, the unit is dedicated solely to electrical production and is not connected to the district heating system. Unit #12 is also the only turbine in downtown that still operates on coal, all other turbines have been converted to natural gas or oil.

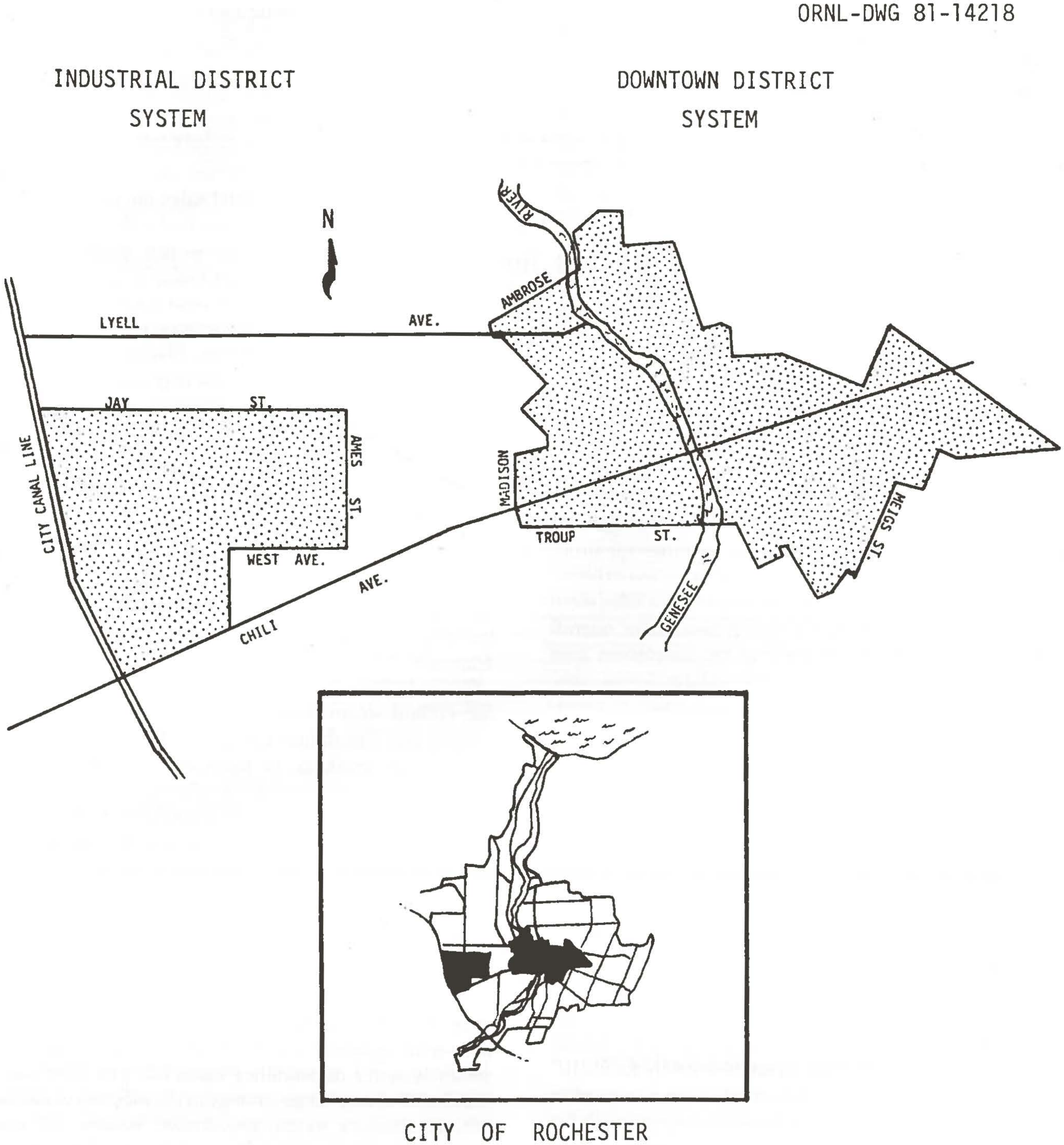

Figure 1.
Franchise area for the Rochester Gas and Electric's steam district heating system.

RG&E has already considered conversion of Unit #12 to cogeneration but rejected the concept due to loss of electrical production, the need for increased supplies of demineralized water, and a concern for possible turbine damage. One potential solution to minimize electrical production losses would be reduction of the steam supply pressure to the district heating system. An attempt should be made by RG&E to determine the requirements for operating the steam system at a supply pressure of 100-150 psig (790-1135 kPa) for a large portion of the year. The system cannot be expected to operate continually at these lower pressures due to the need for high pressure steam during periods of peak demand. However, operation at 100 psig (790 (kPa) for coal-fired Unit #12 for most of the year should result in a significant reduction in oil consumption.

A preliminary heat balance was performed with steam extracted at 96 psig (763 (kPa) from the intermediate pressure section of the turbine.[3] The suitability of extracting steam at 96 psig (763 kPa) is a question that can only be fully answered by the turbine manufacturer. However, if 150,000 lb/hr (158 GJ/hr) could be safely extracted from Unit #12 for district heating, 47% (1.0 PJ/hr or 165,000 bbl of oil equivalent) of the oil used for cogeneration in the Downtown system could be displaced. If conversion of Unit #12 could only provide a flow rate of 50,000 lb/hr (53 GJ/hr), 16% (.34 PJ/yr or 55,000 bbl of oil equivalent) of the oil used in the Downtown system could be displaced. Translated across the entire Rochester system, conversion could reduce dependence upon scarce fuels by 10-30% depending upon the flow rate.

With lower steam pressures, the thermodynamics of cogeneration become more favorable. Presently, the district heating system is supplied by exhaust steam from topping turbines with steam cost allocated at a rate of 90% of the high pressure steam. The thermodynamics of the cost allocation calculation for steam extracted at 96 psig (763 kPa) indicate an exhaust steam charge of 62% of the high-pressure steam charge.[3] RG&E is presently using $1.50/10^6$ Btu ($1.42/GJ) for coal in Unit #12 with an estimated high-pressure steam cost in the range of $3-4/10^6$ Btu ($2.85-4.22/GJ). A capital charge of at least $2/10^6$ Btu ($1.90/GJ) could be applied to steam sales for conversion costs. The capital cost would increase steam cost to approximately $4.50/10^6$ Btu ($4.26/GJ), a price significantly below the $5.60/10^6$ Btu ($5.31/GJ) currently being charged for exhaust heat energy from the cogeneration units at Station #3.

Due to all the possible variations in both turbine modification and cost allocation calculations, there is a definite need for innovation in determining the most appropriate configuration and operational procedures for utilizing the full potential of Unit #12.

Refuse Incineration with Heat Recovery

A unique opportunity exists in the Rochester area to utilize municipal solid waste as a potential source of energy for the district heating system. The county (Monroe) has constructed a sophisticated resource recovery facility within 3 miles (4.8 km) of Station #9 (Industrial District system) and 5 miles (8 km) from Station #3 (Downtown system). The Monroe County Resource Recovery Facility is capable of producing 1200 tons/day (109 x 10^3 kg/day) of high quality refuse derived fuel (RDF), half of which may be available for the district system (Table 1). The approximately 660 tons/day (60 x 10^3 kg/day) of RDF represents a potential low cost heat source which is suitable for scarce fuel substitution in the Rochester district heating system.

RDF could best be exploited by locating modular incinerators with heat recovery equipment at Stations #3 and #9. The Rochester district heating load is very large, predictable, and capable of accepting all the steam produced from two package incinerators. Preliminary estimates indicate that RDF from the resource recovery facility could supply approximately 50,000 lb/hr (52 GJ/hr) of steam for both.

Assuming 55% recovery efficiency and a steam output of 150 psig (1135 kPa), each unit could supply approximately 300 x 10^6 lb/yr (.32 PJ/yr) of steam. A module at

Table 1. Composition and characteristics of refuse-derived fuel produced by the Monroe County Resource Recovery Facility[4]

Composition:	Paper, plastics, textiles, organics, and other low density materials that have been air classified from coarse shredded municipal waste, screened to remove grit and dirt, and shredded to a fine particle size.	
Characteristics:	Moisture content (as received)	13-25%
	Ash (as received)	17% approx.
	Calorific value (as received)	5000-7000 Btu/lb (1.16-1.63 x 10^7 J/kg)
	Particle size (dry)	90% minus 3/4-in. (1.9 x 10^{-2} m)
	Density (as received)	2-7 lb/ft^3 (3.2-11.2 kg/m^3)

Station #9 could displace almost 16% of the current oil consumption.

The second major consideration in using RDF with modular incineration is RDF's competitive price with oil. The current cost of steam sold to the district system is approximately $6.50/10^6 Btu ($6.16/GJ). Preliminary estimates indicate that modular incineration with RDF could supply steam to the system for $4/10^6 Btu ($3.80/GJ), a substantial savings over current prices.

Hot Water Heat Islands

To justify the investment in conversion back to coal and for modular incinerators, additional sources of revenue must be sought. Portions of the revenue will be derived from connecting both old and new customers within the present service area. A need also exists to connect customers outside of the present service area. Service to these new customers should be the starting point for a modern hot water district heating system. Development of several hot water heat islands at the extremes of the present franchise area would be the beginning of an efficient new system that would not be restricted to the central urban core.

A hot water district heating system offers many advantages over the existing steam system. Hot water can be transported more economically over greater distances than steam. A wider range of energy sources can be utilized for production of hot water. Local opportunities in Rochester include reject industrial waste heat, commercial and institutional boilers, and potential retrofit of RG&E's Russel Station power plant. Another significant advantage of a hot water system is the ability to economically serve a lower heat load density. This means that hot water systems have the flexibility to expand into residential markets and also adapt to the changing energy needs of the community. It is probable that the long-term viability of the Rochester district heating system will be directly linked to the initiation of a hot water distribution system around the present steam system.

SUMMARY AND CONCLUSIONS

The Rochester district heating system is a well maintained system that has been steadily declining over the last decade. The decline represents the combined impact of increased fuel costs and decreased annual steam sales. The commitment by Rochester Gas and Electric (RG&E) in the early 1970s to convert from coal to oil followed by the subsequent oil embargo has resulted in dramatic increases in fuel cost. A massive urban renewal program and the increased cost of delivered steam are credited with declining steam sales. The urban renewal activities have ended in Rochester and steam sales in the downtown area appear stable. Throughout this period of turmoil, the steam system has remained profitable but earns a relatively low rate of return. To insure that the system remains economically viable, there is a need to address the system's immediate problems and to examine the long term outlook for the business.

The immediate problems confronting RG&E are to reduce the system's dependence upon oil and to reestablish the former inner city customer base. The long term problem is to expand the district heating system to economically serve areas with lower heat load densities. Two options have been proposed to address the immediate problems. The first option would convert the existing coal-fired Unit #12 in downtown Rochester to cogeneration. The steam supplied from Unit #12 cogeneration is estimated to reduce oil consumption by at least 10% or possibly as much as 30% annually. The second option involves generating steam from municipal refuse incineration with heat recovery. Strategic location of small incinerators, fueled by locally supplied refuse derived fuel, could reduce annual oil consumption by 20%. Because fuel costs constitute the primary expense to the district heating system, steam produced from coal or municipal solid waste offers the opportunity to stabilize or even lower the cost of delivered steam. As steam prices become competitive with other energy sources, annual steam sales and the number of steam customers are expected to increase dramatically. The prospect of a competitively priced and reliable steam supply should be a positive inducement for new customers to connect to the steam system.

The third option represents a long range strategy for insuring the economic viability of the Rochester district heating system. Current limitations of the steam technology restrict expansion to areas of high heat load density. To be competitive, the system must be capable of expanding into the lower heat load density areas of the city. The third option proposes development of hot water heat islands at the extremes of the existing system. Development of several heat islands could be the beginning of an efficient new system not restricted to the downtown core area. The long term viability of the Rochester district heating system is directly linked to initiation of a new hot water system around the present steam system.

The three proposed options represent only a few of the potential options available for sustaining and improving the Rochester district heating system. Many variations of these options could be employed to accomplish the same objectives. The major challenge that confronts the district heating system is a commitment from the utility and the city to take aggressive and coordinated actions to support the system. The combined talents of the city and utility should be ample to meet the challenge of revitalizing the Rochester district heating system. ■

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