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DISTRICT HEATING IN DENMARK:

Lessons from a Technology Exchange

Prepared for:

The Energy Task Force
of the Urban Consortium
for Technology Initiatives

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OVERVIEW AND SUMMARY

Abstract

A study visit of district heating facilities and related equipment manufacturers in Denmark was conducted in August, 1985, at the invitation of the Danish Board of District Heating, with support from the United States Department of Energy. U.S. members of the study team were selected from the staffs of cities and counties participating in the Urban Consortium Energy Task Force program. The visit included tours of municipal district heating systems in the cities of Odense and Copenhagen, as well as equipment manufacturers in Kolding and in Copenhagen.

The visit represented the first element in a technology exchange program that included the Danish Board's cosponsorship and participation in seminars and workshops in the United States in October, 1985.

This report has been written by Public Technology, Inc., to describe the approaches taken to support district heating in Denmark and to document the experience of the study visit. The report includes questions asked by U.S. participants prior to the visit, their reactions subsequent to the visit, and a summary of the October workshops in Columbus and San Francisco.

Description and Objectives of the Technology Exchange

District heating is a capital intensive energy technology that can provide dependable, reliable and efficient supplies of thermal energy for a wide range of residential, commercial and industrial uses. In Denmark, municipal officials consider district heating systems as a primary mode of heat supply. This is quite the reverse of the common situation in the United States, where district heating systems are rarely considered outside of the context of relatively small, "campus-scale" applications. To examine the reasons for this difference in emphasis, arrangements were made in the early Summer of 1985 for an exchange of visits between local government officials from the United States and district heating practitioners from Denmark. This technology transfer exchange was structured generally as follows:

- At the invitation of the Danish Board of District Heating, representatives from five major U.S. urban governments that were strongly interested in the implementation of district heating systems in their communities were selected as a team for the study visit to Denmark. The U.S. team included representatives from the cities of Atlanta, Georgia; Columbus, Ohio; Kansas City, Missouri; San Francisco, California; and San Jose, California. The members of this municipal team were encouraged to invite participation of a key private party (utility, developer or consultant) from their community who was involved in their local district heating efforts. (See Appendix A for a full listing of the team membership.)

- The Danish Board offered to customize the study visit according to the specific technical assistance needs voiced by the U.S. team. The study visit to Denmark was scheduled for the week of August 19-23, 1985, with an itinerary arranged to address topics of heat source development, distribution and piping networks, and consumer/end user systems.

- To expand the benefits of the study visit beyond the direct participants on the U.S. team, two regional workshops were scheduled for the week of October 28 through November 1, 1985; one in Columbus, Ohio, the second in San Francisco, California. Members of the Danish Board would provide a major portion of the presentations at both workshops.

- Results from the Danish study visit were integrated into the presentations by the U.S. municipal staff at both the Columbus and the San Francisco workshops for the benefit of other city and county representatives attending.

Findings from the Study Visit

District heating works in Denmark -- it is currently a major element of the country's energy production and distribution system, and it is projected to become the predominant element by the end of this century. Significant causative factors for this major emphasis, and key components of the successful Danish approach to district heating are summarized below.

Significant Causative Factors

Four causative factors present much more in Denmark than in the U.S. appear to have influenced the growth and success of Danish district heating systems:

- High Energy Prices -- Denmark is a small country that has few indigeneous energy resources. Heavily dependent on imports from the world market, the country has, by necessity, historically emphasized high efficiency technologies to reduce energy costs. Massive price rises for petroleum products in the 1970's provided a direct impetus for increased national support for energy-efficient district heating.

- Lack of Natural Gas -- Until recent years, natural gas was generally unavailable in Denmark, and will be available to only limited areas of the country in the future. This constraint denies to Denmark a fuel that in the U.S. is a plentiful, non-polluting and relatively inexpensive energy resource for individual heating systems.

- Air Quality Problems -- Environmental concerns were of great significance in Denmark's urban centers because of large, concentrated numbers of individual oil or coal fired domestic furnaces. Emissions from large centralized combustion plants are more easily and cost-effectively controllable than are those from individual furnaces, another key factor that supports district heating.

- Mixed Use Development -- Land development in most Danish cities shows more integration among industrial, commercial and residential uses than is the normal U.S. case. Such integration helps balance thermal loadings for a district heating system since each type of use has somewhat differing peak loads and seasonal demands.

The Danish District Heating Approach

The causative factors summarized above are not, by any means, a comprehensive list of why district heating is a major emphasis in Denmark. They are, however, important indicants of an overall ethos among the Danish populace that supports strong measures for the efficient management of limited resources. For district heating, these measures combine the three components of national legislation, technical standardization and effective management approaches:

- National Legislation -- The Danish national Heat Supply Act mandates that each municipality and county prepare and submit to the Danish Minister of Energy for approval a heat supply plan for their jurisdiction. Consideration of heat supply alternatives, to include refuse incineration, industrial waste heat recovery, and district heating, as well as economic sensitivity analyses of these alternatives, are explicit requirements for each heat supply plan. The practical effect of this heat supply planning requirement is a virtual guarantee that higher density areas are targeted for district heating development.

- Technical Standardization -- The vast majority of thermal energy for Danish district heating systems is produced by combined heat/electrical power plants, and is distributed to consumers in the form of hot water in piping systems that can be up to 60 miles in length. A high degree of standardization exists among each element for a district heating system -- from heat production through distribution mains and end user equipment. Standardization decreases complexity and costs for district heating, allows the easy use a variety of heat sources, and encourages the integration of small systems into large, efficient networks over time.

- Management Arrangements -- Responsibilities for the development, ownership and operation of district heating systems are generally defined in three interlocking, cooperative layers composed of production companies, transmission companies and distribution companies. While some of the distribution systems are owned and operated by municipalities, the majority are operated as partnerships and cooperatives among the companies, the municipalities and their consumers. Financing for the systems is structured so that they "pay their own way" without public subsidy.

The significance of this integration of legislation, technology and management is not that this specific model is the <u>only</u> one that will work. Rather, its importance is as an illustration of how all three elements can be combined in a mutually supportive structure to encourage district heating and to capture the real benefits associated with its use.

More detailed discussions of each element in the Danish approach are included later in this report, with specific examples of their application to the Odense and Copenhagen systems. Reactions from the U.S. study team, and comments from the cities of San Francisco, Columbus and San Jose on features of this approach are contained in Appendix C. These comments are strongly recommended for readers desiring a more extensive discussion of how the Danish approach and experience can be translated to municipalities in the United States.

DISTRICT HEATING -- U.S. AND DANISH PERSPECTIVES

An Overview

District heating and cooling (DHC) is an energy technology that provides thermal energy from a central plant in the form of steam, hot water and/or chilled water through a network of pipes to meet the needs of connected users. The high density development found in urban areas is usually considered essential for the cost-effective operation of these systems. First developed in the United States more than a century ago, district heating systems grew substantially until the the 1930's when the availability of plentiful supplies of oil and natural gas for on-site heat production <u>and</u> the siting of large electric generation facilities away from dense urban centers began to reduce DHC's significance as an economically viable energy supply technology.

Despite a recent resurgence of interest in DHC at the Federal and local levels and within the private sector, operating district systems supply only about one percent of the total demand for space and hot water heating in the United States. In contrast, DHC is used extensively in European nations. As examples, Denmark and the Soviet Union provide over 40% and 70%, respectively, of their space conditioning requirements through district systems. A major reason for the high use of district heating in these two countries is the existence of national policies that strongly promote new and expanding systems. These policies are based on the inherent practical economic and engineering advantages of district heating:

- Fuel Efficiency

  A well designed, cogeneration-based district heating system can have a fuel-to-energy conversion efficiency of up to 80%. This level of efficiency is substantially higher than the norm for the separate production of electric and thermal energy in individual facilities.

- Fuel Flexibility

  A district heating system can use thermal energy from almost any combustible material, from a variety of alternate energy resources, from municipal solid waste, and from "wasted" energy recovered from commercial or industrial operations.

- Price Stability

  The combined effect of increased conversion efficiency and the flexibility to use fuels that are most available and least costly regionally and nationally helps stabilize consumer costs and decreases the need to "export" monies for non-indigenous fuel supplies.

- Environmental Performance

  Combustion of fuels in a central plant, rather than in smaller, individual residential, commercial, or industrial furnaces, can support the cost-effective installation of sophisticated pollution control equipment.

- Economic Development

  A district heating system is a long lived, capital intensive facility that can create substantial employment opportunities during its construction phase. Moreover, DHC represents an infrastructure "magnet" to attract urban development from its ability to deliver continuing stability in energy supply and price.

These multiple benefits are valid on both sides of the Atlantic, but the extent of support and use of DHC is much greater in Europe than in the U. S. An overview of Denmark's applications of district heating demonstrates this difference in emphasis.

The Danish Experience

With a total population of just over 5 million, Denmark supports one of the most effective, cost-efficient district heating programs in the free world. Expanded substantially since the second world war, the country currently contains approximately 350 district heating systems; 50 are municipally owned and the remainder operated as consumer cooperatives. With very few exceptions, these systems use hot water, rather than steam, as the media for thermal distribution. Currently, district heating facilities provide nearly 40% of Denmark's total non-industrial heating energy supply. As national policy, Denmark intends to increase this penetration to 50% of total heating energy supply by the end of this century. Summary data describing the extent of district heating in Denmark is shown in Table 1.

While numerous other factors have affected the success of district heating in Denmark, three primary elements characterize the country's overall approach: (1) supportive national legislation; (2) generally standardized technology; and (3) sound management arrangements.

Supportive Legislation

In 1979, the Danish government passed a national Heat Supply Act that assigns responsibility for the planning of heat supply systems to the Danish Minister of Energy and the country's county and municipal councils. The basic objectives of the Act are to promote the most economical use of energy for the provision of space heating and hot water supplies, while reducing dependence on oil imports. The Act strongly encourages conversions from

Table 1 -- Summary of Danish District Heating (1981)*

Population and Housing	-- 5.2 million total (1.5 million Copenhagen) -- 2.0 million housing units (60% single family) (40% multifamily)
Annual Energy Demand (including electricity)	-- 570 trillion BTU
Annual Heat Demand (excluding industry)	-- 190 trillion BTU
Heat Supplied as District Heat (42% of heat demand)	-- 80 trillion BTU
Total District Heating Systems (Transmission & Distribution)	-- 350 systems nationwide (300 cooperative) (50 municipal)
Length of Double Pipe Grid (Excluding service branches)	-- 5,800 miles nationwide
District Heating Load Factor (Nationwide average)	-- 43%
Delivered Heat Price Range (Varies based on local distribution system)	-- $5 to $10 per million BTU

*Source: District Heating and Combined Heat and Power Systems: A Technology Review (IEA, 1983) individual to collective (district) heat supplies wherever it is economically advantageous to do so.

Significantly, the Act does not mandate district heating, but it does mandate the preparation of "Heat Plans" at both national and local levels. The heat plans have the practical effect of defining geographical areas of three general types:

- Densely populated areas are primary targets for district heating systems, with thermal energy provided from combined heat and power plants.

- Medium-density areas are secondary targets for combined power and heat district heating systems, but may also use natural gas-fired collective or individual systems.

- Low-density areas are not targets for district systems, emphasizing instead electricity and renewables.

While individual residents and businesses are not required to connect to a district heating system, economics generally offer a sufficient incentive for connection. As a result of the heat plans, about one-half of Denmark's two million households should be supplied by district heating from combined power plants and gas or coal fired thermal-only plants by the year 2000, with natural gas, oil, electricity and renewables accounting for the remaining households.

Standardized Technology

The Heat Supply Act combined with the district heating efficiencies discussed above, have led to the development in Denmark of a relatively standardized technology to support both long transmission lines and system interconnections. Standardization affects the choice of the thermal medium and piping mains, as well as the design of both transmission and distribution systems.

- Thermal Medium -- hot water is normally used as the thermal medium in Danish district heating plants, allowing transmission networks of 20-30 miles as a norm, and providing the potential for transmission distances of 60 miles or more.

- Piping Mains -- prefabricated, preinsulated piping mains are available in a wide range of sizes and are normally buried at shallow depths of three to six feet.

- Transmission Systems -- transmission systems are normally designed to carry hot water from a heat plant at pressures of up to 360 psig, with production temperatures of 212-249 degrees F and return temperatures of 140 to 158 degrees F.

- Distribution Systems -- heat is delivered from the transmission mains to the local distribution systems via heat exchangers at local substations. This avoids the mixing of hot water media between the transmission and distribution networks. To allow direct connection to consumer installations, the distribution networks normally operate at pressures below 95 psig and at supply temperatures of 176-194 degrees F.

Standardization makes possible the integration and linkage of previously independent systems to capture the economic benefits of large and diverse heat sources (electric power stations, refuse incineration plants, industrial waste heat, etc.) that might not be fully used in smaller, separate systems. It also provides a realistic basis for a general approach to district heating, stated best by Lennart Larson, Vice-mayor of the city of Odense, as: "Start small, think big, think link!"

Management Arrangements

Standardization of technology is important to allow the Danes to "think link" and to support the engineering capability for systems integration. Such integration could not occur, however, without equally sound procedures for administrative and financial management. All energy companies in Denmark are non-profit. Some district heating systems in the country are owned and operated by municipalities, but the majority of the systems are operated by interlocking partnerships and cooperatives among the companies, the municipalities and their consumers.

As separate systems continue to "link", responsibilities for the ownership and operation of large integrated systems will generally be defined in three interlocking, cooperative layers composed of production companies, transmission companies, and distribution companies.

- Production companies deliver heat to the transmission companies under formal agreements between the two parties. Production companies are responsible for establishing, financing, operating and maintaining the thermal production system.

- Transmission companies buy heat at a wholesale price from the production companies and sell this heat to the individual distribution companies. Transmission companies are responsible for establishing, financing, operating and maintaining the transmission system, to include heat exchangers and coordination of the heat production process.

- Distribution companies buy heat from the transmission companies and deliver this heat to individual consumers. Distribution companies are responsible for establishing, extending, financing, operating and maintaining the distribution system, with additional responsibility for the production of heat in peak load and emergency situations.

Each company is allowed to charge a price sufficient to recover its costs over a typical period of 20 years. Systems in place to date have been successfully financed through the European Investment Bank with the municipalities involved as guarantors. End user charges to cover these costs are typically based on the amortization of capital costs over the 20 year period, with operating and maintenance costs following the general rate of inflation. Any deficits in the the early years of operation, before the system is operating at capacity, are included as part of the capital financing.

Prices for heat delivered from the transmission companies to the distribution companies are forecasted to stay within a range of $4 to $11 per million BTU over the next 20 years. Prices charged to consumers by the distribution companies will cover a wider range usually based on a combination of: (1) a fixed charge related to the customer's installed load capacity; (2) a variable charge based on heat or water volume consumed; and (3) a connection charge related to the costs of installation of supply and return lines to the consumer.

DESCRIPTION OF THE DENMARK STUDY VISIT

The U.S. team of municipal professionals assembled by the Energy Task Force visited Denmark during the week of August 19-23, 1985. The intent of this visit was to provide an intensive overview of Denmark's district heating processes to support similar efforts in the U.S. The itinerary was designed to include visits to functioning district heating systems, to equipment manufacturers, and to engineering firms involved in the planning and implementation of these systems. The remainder of this report summarizes key questions from the U.S. participants, the itinerary for the visit and results for each event on the itinerary.

Key Questions from the U.S. Team

Prior to the visit, each municipal member of the U.S. team was requested to define key questions for which he or she expected assistance from the members of the Danish Board. A summary of these questions follows, with a more complete listing of the questions contained in Appendix B.

From the City of Columbus:

Questions from the Columbus staff focused primarily on the definition of factors that favored the development of district heating in Denmark, and how those factors differed from conditions in the United States. Of special interest were considerations of marketing and economics, financing and revenues, forms of municipal involvement/ownership, and national subsidies or incentives for district heating systems. Other questions centered on the planning processes used in Denmark, the methods used to make expansion decisions, the practical value of a district heating system as an economic development attractor, and practical techniques for pollution control on coal-fired furnaces.

From the City of San Francisco:

Questions from the San Francisco representative covered some of the elements of economics, planning and marketing similar to those expressed by Columbus, but focused also on the technical characteristics of the Danish systems. Of particular interest were questions on mains installation in a congested urban area, interconnect technologies for hybrid steam/hot water systems, insulation materials for piping, integration of heat pumps, and use of computer controls for system operations. Other questions centered on sizing for base and peak thermal loads, apportionment of costs between thermal and electric production for a cogenerating system, and the Danish experience in district cooling applications.

From the City of San Jose:

Questions from the staff of the city of San Jose covered a range of operating, maintenance and billing concerns. Primary interests were expressed in techniques to accomodate multiple fuel systems (e.g., heat sources ranging from refuse incineration to natural gas in a single network), procedures used and skills necessary for system maintenance, patterns and controls for peaking operations and emergency operations, and procedures used for customer billing. Questions were also asked for the Danish methods to deal with hazardous waste management, wastewater management, and energy standards for buildings.

From the City of Atlanta:

Questions from the city of Atlanta combined elements of all three of the earlier described representatives. Similar interest was voiced for questions related to economics and marketing, for ownership and financing, and for procedures and skills necessary for system operation and maintenance. A strong emphasis, however, was placed on how these questions would relate to the rehabilitation of an existing, natural gas-fired, thermal-only steam district heating system like the one currently operating in the city of Atlanta.

Responses to the Questions

These questions were prepared to provide both a focus for the visit, as well as an aid in setting its itinerary. The questions were restated in various forms to the Danish professionals during the visit, with their responses given in both verbal and written forms. Comments from several members of the team on how this experience can be translated into the American municipal environment are contained in Appendix C of this report.

Itinerary

The itinerary for the study visit was designed to cover the large district heating installations in the city of Odense on the island of Funen, in Copenhagen on the island of Zealand, and a tour of manufacturing facilities in Kolding, Jutland.

Monday, August 19 -- Odense:

- Odense district heating transmission and distribution system, including new construction sites;
- Fynsvaerket combined heat and power plant, including heat, electricity and pumping facilities;
- Meeting with Odense Vice-mayor Lennart Larson for review of the Odense system construction and operation process;

- Tour of various buildings connected to the Odense system, including commercial and residential installations.

Tuesday, August 20 -- Odense and Kolding:

- Tour of heat exchanger manufacturing facility, Pasilic-Therm, in Kolding;
- Tour of preinsulated piping manufacturing facility, Durotan, in Kolding;
- Presentation of heat meter, pipe, heat exchanger and control equipment by DBDH members in Odense;
- Presentation of engineering and planning expertise by Harry & Mogens Larsen, A/S, in Odense.

Wednesday, August 21 -- Copenhagen:

- Tour of heat meter manufacturing facility, ISS Electronics, in Copenhagen;
- Presentation of lubricated district heating valves by staff from Brdr. Christensens Haner, A/S.

Thursday, August 22 -- Copenhagen:

- Overview of district heating planning by staff of Cowiconsult and firms of Ramboll & Hannermann and B. Hojlund Rasmussen;
- Tour of suburban Avedore district heating system serving an industrial park;
- Tour of Brondbystrand district heating system and oil-fired heat-only boilers for residential customers;
- Tour of Vestforbraending refuse incineration plant connected to the Copenhagen district heating network.

Friday, August 23 -- Copenhagen:

- Presentation of Copenhagen central municipal district heating system by the firm of B. Hojland Rasmussen;
- Final presentation on Danish district heating planning and wrap-up of study visit at offices of B. Hojlund Rasmussen.

Summaries of the activities listed above are presented in the remaining sections of this report.

The Odense District Heating System

Odense is a city with a population of 170,000 that owns and operates its district heating transmission and distribution systems. The Odense system was begun in 1929 with a small combined heat and power facility providing hot water to about 500 homes. The first major expansion of the system occured in 1953 with the construction of the large, coal-fired Fynsvaerket combined heat and power plant on the outskirts of the city. About 90% of heat demand (38,500 homes) in Odense is supplied by district heating. Summary data for the Odense system is shown in Table 2.

Heat supply planning in Odense has divided the city into a total of 36 "heating districts", with 21 to be fully served by district heating by the year 2000. Of the remaining districts, 6 will be supplied by natural gas and the balance by fuel oil. District heating is currently available to 95% of properties located in the 21 designated district heating districts. Because of the relatively small heat load in comparison to the size of the Fynsvaerket power plant, no need for the construction of new base load thermal facilities is foreseen. For line extensions, mobile oil-fired boilers are commonly used to supply new development until permanent transmission lines can be economically extended to the area.

Heat production is provided primarily by the Fynsvaerket plant, a cogenerating facility with a capacity to produce 658 MW of electric power and 769 MW of thermal power. This plant supplies over 90% of the annual heat requirements for the Odense system, with the remainder supplied by local oil-fired peaking boilers. During peak periods, these boilers can account for up to 40% of total heat production. An insulated hot water storage tank in the plant has the capability to supply the entire district heating load for 1.5 hours in the event of high electric load or for unexpected plant outages. At full load, the plant produces eight units of heat for each unit of electricity.

Heat transmission from the Fynsvaerket plant occurs through seven transmission mains supplying heat to local distribution companies. Five of these mains are connected to the Odense distribution network; the other two supply an additional two towns and a commercial greenhouse development. Fynsvaerket supplies hot water for the transmission system at a supply temperature between 180-205 degrees F. and a pressure of about 230 psig. Control of the transmission main output occurs at the generating plant.

Distribution systems that deliver heat to customers interconnect with the transmission mains at local substations. Differing from more conventional practice, the Odense system uses pressure reducing valves or pumps at the substations, rather than heat exchangers, to lower pressure in the distribution system to about 90 psig. The Odense system currently has 24 substations, 15 of which include oil-fired peaking boilers.

Table 2 -- Summary Data for Odense District Heating

Population and Housing	-- 170,000 total population -- 44,000 total homes (38,500 with district heat)
Heat Supply Plan Districts	-- 36 total heat districts -- 21 for district heat -- 6 for natural gas -- 9 for oil & renewables
Heat Production in 1985 (from Fynsvaerket)	-- 10 trillion BTU total -- 7.6 trillion BTU used in Odense municipal system
Odense Transmission and Distribution System	-- 730 miles of double pipe -- 10 pump stations -- 15 oil fired peaking stations (510 MW) -- Direct use (heat exchangers not used for residential customers)
Piping System Construction	-- Early = concrete ducts -- 1960's = sliding steel in polyurethane foam -- 1970's to date = preinsulated pipes
Consumer Metering and Costs (1985 U.S. $ estimates)	-- Meter by water volume used -- $5.22/million BTU average -- $355 annually for typical 1,200 sq. ft. home

*Source: Data provided by Odense municipal officials

Piping for the Odense system is composed of about 730 miles of double (supply/return) mains in the transmission and distribution systems. Prefabricated, preinsulated piping is used for all new extensions and has replaced concrete ducts used for the initial system.

Customer connections are typically direct for space heating, with heat exchangers for domestic hot water. Since radiators connected to the system can tolerate the distribution pressure of 90 psig, this approach minimizes the need for additional interface equipment and is very inexpensive for the consumer. Flow to the radiators is regulated by pressure differential or, in newer systems, by thermostatic control and a time programmable clock. Payment for hot water is made on the basis of water volume metered in the customer's return line.

Ownership, operations and financial responsibilities for the entire system generally follow the model previously described for Danish district heating:

- Heat Production -- the Fynsvaerket combined power plant is owned and operated by a cooperative partnership of the municipalities of the island of Funen. Of the projected total 1985 heat production of 10 billion BTU, the city of Odense will use about 76%, with the remainder sold to other connected towns and greenhouse gardeners. The city of Odense pays for thermal energy produced at Fynsvaerket on the basis of electric energy that could have been produced had no thermal energy been extracted from the plant, plus a negotiated annual surcharge (33% in 1983) of this cost. In 1983, heat revenues accounted for about 25% of the plant's total revenues.

- Transmission and Distribution -- five of the seven transmission mains from Fynsvaerket are owned and operated by the city of Odense; one main serving two smaller towns is owned by Fynsvaerket; and one main is owned by the Stige Gardeners Corporation. The entire distribution system for Odense, to include the substations and the peak load plants, is owned and operated by the City.

- Typical Costs -- In 1985, thermal energy was delivered to customers in the city of Odense at an average cost of $5.22 per million BTU. Customers are billed on a formula basis that includes allocations for administration, fixed capital and operating costs, and actual energy used. From 1982 to 1985, the annual cost for heating and hot water for a typical 1,200 square foot single family house in Odense was both inexpensive and stable, ranging from $355 to $380.

The Copenhagen District Heating System

Copenhagen is the largest city in Denmark with a population of well over one million. Approximately 40% of the city's heat demand is currently supplied by district heating, with plans for an expansion to 85% of total heat supply by the year 2002. The Copenhagen system was begun in 1925 from a small power plant in the center of the city. Today's metropolitan area system includes 18 municipalities with a total of 500,000 dwelling units connected to district heating. Heat is produced from a number of combined heat/power plants, refuse incineration facilities and coal or oil fired heat-only boilers. Summary data for district heating in Copenhagen is shown on Table 3.

Heat supply planning for the Copenhagen metropolitan area, because of its size and complexity, is much more involved than was the case in Odense. As mentioned above, heat supplies are provided by several combined heat and power plants, a refuse incineration plant, and a sludge-burning water purification plant. Transmission and distribution systems are owned and operated by the city. In the adjoining 18 municipalities, heat supplies are provided by 60 local coal or oil fired heat-only boilers, and (in two municipalities) by a jointly owned refuse incineration plant. Local distribution systems are owned and operated by the municipalities or by consumer cooperatives.

The heat supply plan anticipates interconnection of all of these systems by the year 2002 with the two goals of: (1) virtually eliminating the use of imported oil, and (2) supplying 85% of the projected heat demand of 30 trillion BTU per year through district heating. Key elements in the plan include:

- Construction of two new 235 MWe coal-fired cogeneration plants, each of which will have a heat capacity of 330 MW;
- Construction of two major transmission systems to integrate the metropolitan network. These interconnected systems will have a total length of 100 miles, with pipe diameters of up to 48 inches;
- Creation of two new transmission companies to finance, construct, own and operate the new transmission systems;
- Extension of distribution systems to consumers by the existing muncipal and cooperative distribution companies.

The Metropolitan Copenhagen heat supply plan is an excellent illustration of the potential for district heating to integrate a wide range of heat supply facilities among multiple jurisdictions. With its long distance transmission network, the system will effectively use heat sources that could not be fully used in

Table 3 -- Summary Data for Copenhagen Metro District Heating

	1983	2002
Annual Heat Demand (BTU)	27 trillion	30 trillion
District Heat Supplied (BTU)	12 trillion	26 trillion
Maximum Load (MM BTU/hr)	N/A	8,013

Projected Capacity of Primary Production Units (MM BTU/hr)

• Refuse incineration plants	317
• Water purification plant (sludge)	41
• Amager power stations, Units 1 & 2	989
• Amager power stations, Unit 3	1,125
• Avedore power station, Unit 1	1,125
• Surplus from existing steam system	1,160

Transmission System

• Total length, "CTR" system	37 miles
• Total length, "VEKS" system	63 miles
• Pipe diameters	8-48 inches
• Hot water supply temperature (F)	203-248 deg.
• Hot water return temperature (F)	122-140 deg.

Estimated Total Constructon Costs (1984 prices)

• Power stations (share allocated to heat)	US $ 87 million
• "CTR" transmission system	US $142 million
• "VEKS" transmission system	US $116 million
• Distribution system expansions	US $358 million

Estimated Savings and Return

• Oil replacement (full implementation)	4.2 million bbl/yr
• Net energy savings (")	2.6 million bbl/yr
• Internal rate of return	20%

*Source: The Danish Approach to Utilities Integration. Paper delivered by Kim Trojberg (BHR) to National Research Council. June, 1984.

smaller, separate systems. Such systems integration requires sound planning and engineering skills, and very close cooperation among a large number of governmental and private organizations.

Heat production facilities in the Copenhagen area include combined heat and power plants similar to the Fynsvaerket plant near Odense. To provide illustrations of other types of facilities, plant visits around Copenhagen focused on three differing types of heat production facilities, all of which will eventually be linked into the Copenhagen metropolitan system:

- Refuse Incineration -- The Vestforbraending facility, located just west of Copenhagen, is a 1,200 ton per day, mass burning refuse incineration and resource recovery plant. Owned jointly by a cooperative of 12 local municipalities, the plant provides hot water for these, and three other, jurisdictions under contract. A heat-only plant, the facility has a generation capacity of 1.4 billion BTU annually. As a significant difference from mass burn facilities in the U.S., waste coming to the plant is successfully presorted by households into five categories of combustible, noncombustible and recyclable materials.

- Residential Heat-Only -- The municipality of Brondby, near Vestforbraending, owns and operates a heat production plant that supplies district heat for 30,000 of its total population of 38,000. 80% of a total heat production capacity of 166 MW is provided by three automated heavy oil boilers, while the remaining 20% is provided from a refuse incineration plant. With the Danish emphasis on "cooperation", the waste for this incineration plant is received from the Vestforbraending service area.

- Industrial Heat-Only -- The Avedore district is a 1,100 acre industrial park created by diking and filling a shallow bay near Copenhagen. Its self-contained district heating system is supplied heat by three oil fired heat-only boilers with a combined capacity of 100 MW.

Heat transmission systems, as proposed in the Copenhagen heat supply plan, will be substantially expanded to link distribution systems in 18 municipalities. The completed hot water network will be designed for a standard pressure of 360 psig, a supply temperature of 248 degrees F., and a return temperature of 158 degrees F. When fully completed, the system will provide both a ring through the area of Copenhagen, as well as two essentially straight line extensions to a distance of more than 25 miles beyond the city.

Distribution systems will interconnect with the transmission mains through heat exchanger substations, rather than using pressure reducing valves as is the case in Odense. Distribution system temperatures and pressures will be similar to those in

Odense, with pressures of about 95 psig. When the heat supply plan is fully implemented, currently operating oil fired heat-only plants will be maintained by the distribution companies, but will be used only to meet occasional peaking demands or for emergency outages.

Piping will consist primarily of prefabricated, preinsulated mains in both the transmission and distribution networks. Pipe diameters for the transmission system will range from 8 inches to 48 inches.

Customer connections to the majority of existing customers are similar to those in Odense, with direct connection to the distribution network, rather than through intermediary heat exchangers. New installations, however, are beginning to use heat exchangers with greater frequency primarily for safety reasons. Where it is necessary to raise temperatures to serve special facilities (e.g., hospitals and industry at requirements of 340 degrees F. or above), heat exchangers are a normal requirement.

Ownership, operations and financial responsibilities will again follow the three layered Danish model for production, transmission and distribution systems. Several special differences for the Copenhagen systems are worth mentioning:

- <u>Transmission and Distribution</u> -- local distribution systems will be extended and operated by the existing distribution companies. The two new transmission systems, however, will be financed, owned and operated by two new transmission companies:

  -- "CTR", already founded, will be responsible for 37 miles of transmission mains in the main area of Copenhagen, to include a tunnel under Copenhagen Harbor. CTR will be owned by five municipalities in the center of the metropolitan area.

  -- "VEKS", to be founded in the near future, will be responsible for 63 miles of transmission mains to the west of Copenhagen. VEKS will be owned by eleven municipalities in the western part of the metropolitan area.

- <u>Cost Estimates</u> -- Total capital cost for the planned expansion of the Copenhagen metropolitan system, in 1984 U.S. dollars, will total slightly more than $700 million. This total can be allocated generally to the separate parts of the system expansion as $90 million for heat production increases, $250 million for the transmission system, and $360 million for expansions to the distribution system.

- <u>Savings and Return</u> -- According to the consulting engineers for the heat supply plan, the effects of full implementation of the system will be an oil replacement of over 4 million barrels per year, a net annual energy savings equivalent to over 2.6 million barrels of oil, and an internal rate of return of 20% for the total investment.

Preinsulated Prefabricated Piping

Preinsulated pipes are normally used in modern Danish district heating systems. Pipes are manufactured in varying lengths and diameters by injecting a polyurethane foam between an interior steel pipe and a high density polyethylene outer casing. When the foam is injected, it expands to fill the space between the inner and outer pipes, then hardens to form a firm bond between them. Expansion joints, bellows and similar connections cope with thermal stress for pipe lengths in network installations.

Demonstrations of the pipe manufacturing process were given at the Durotan pipe factory in Kolding, Jutland (since bought by the firm of I. C. Moller). Pipes are manufactured in straight lengths, curves and tees in lengths ranging to 50 feet and diameters up to 48 inches.

Heat Exchangers

Heat exchangers allow the transfer of heat from one liquid to another without the mixing of the two liquids. At the Pasilic-Therm manufacturing plant in Kolding, Jutland, the manufacturing process for plate heat exchangers was demonstrated. Plate heat exchangers are made of corrugated plates of stainless steel, tungsten steel, or titanium (depending on the need for resistance to corrosion) that are arranged to form a series of parallel channels. These plates are clamped in a frame that allows entry, separation and counter-flow of two liquids between alternating plates. This arrangement allows the transfer of heat between the liquids flowing in each layer of the plate without mixing of the fluids.

Plate heat exchangers are normally used for large installations in power plants, distribution substations and industrial applications, and are also made in smaller sizes for residential uses. A more common type of heat exchanger for residential uses, however, is a coil "pipe-in-pipe" system seen in several residential apartments in Odense. The principles for operation of the pipe-in-pipe exchanger are similar to those for the plate exchanger, but concentric pipes are substituted for the multiple plates.

Hot Water and Heat Meters

Most existing district heating systems in Denmark charge customers for heat based on a measurement of the volume or flow of water used -- a practice made possible by the usually low variation of temperatures in the supplied hot water. More accurate measurements can. however, be made with the use of heat meters that sense both flow and temperature to record the actual amount of heat extracted and used by a customer.

At the Clorius Combimeter Division of ISS Electronics near Copenhagen, an electronic heat meter was demonstrated. Operating on Faraday's principle that a fluid flowing through a magnetic coil induces a voltage proportional to the flow, the Clorius meter adds temperature sensing and integrating devices to record both flow and temperature changes resulting from a customer's use of district heat.

District Heating Planning

The final event for the study visit was a presentation and discussion of planning methods used in Denmark for district heating. Led by members of the firms of Cowiconsult, B. Hojlund Rasmussen, and Ramboll and Hannemann, the discussions focused primarily on the Danish methods for integration of heat supply, transmission and distribution systems, especially focused toward eventual large regional systems.

Normally, a single planning team that may be composed of a number of firms is given the responsibility for planning, design, procurement, construction supervision and general management activities for a major system's development or expansion. This arrangement is intended to assure both sufficient expertise and continuity through the implementation process as a guarantee of the project's success.

Presentations of special interest were given by Kim Donald Trojberg from the firm of B. Hojlund Rasmussen who described the planning and design process in four major components:

- Locating, quantifying and forecasting heat demands over a 20 year time frame;
- Identifying the location of primary heat production units and specifying unit loadings in terms of base load, peak hour and annual supply;
- Designing the transmission mains system, to include pipe sizes and routing, pump and heat exchanger equipment, and interface with local distribution networks.
- Economic analyses, to include the financial sensitivity of the plan to design options and phasing alternatives.

Mr. Trojberg summarized his use of computer models for both the technical design of systems and for the financial analysis of their cost-effectiveness. Specific examples of the use of this process and the models were provided for district heating projects in the cities of Aarhus, Copenhagen and the Triple Town area of Jutland.

Summary and General Conclusions

As an obvious conclusion, district heating works in Denmark -- it is currently a major element of the country's energy production and distribution system, and it is projected to become the predominant element by the close of this century. At the national level, Denmark is committed to significant expansion and supports this commitment with a sound structure for heat supply planning and management. Integration of separate heat systems is a formal part of this structure that is made possible by a combination of technical standardization, domestic engineering experience and manufacturing expertise, and a populace that generally knows and favors district heating. Other general conclusions made as a result of the visit include:

- The cost-effectiveness of Danish district heating is largely attributible to the high conversion efficiencies from combined heat and power generation facilities.

- These conversion efficiencies, coupled with the long distance transmission capabilities of hot water media, support the economics of serving a substantial residential market.

- Danish district heating technology, in the broad sense, is not significantly different from new applications being considered in the U.S. There are, however, substantial differences in market acceptance, in broad technical standardization, and in institutional arrangements.

- A key difference in institutional perspectives is that district heating distribution at the local government level in Denmark is commonly seen as a normal public works operation -- a rare perception in U.S. municipalities.

- Finally, two causative factors present much more in Denmark than in the U.S. appear to have influenced the success of district heating:

  -- Environmental concerns were of great significance because of significant numbers of individual oil or coal fired furnaces in urban areas, a key reason to switch to more easily controlled central combustion plants; and

  -- Natural gas was generally unavailable in Denmark until recent years, and will be limited in the future, denying to this country a fuel that in the U.S. is plentiful, non-polluting and relatively inexpensive for individual heating systems.

More substantial reactions from the study visit were developed by several of the participants on the U.S. team. Comments from the cities of San Francisco, Columbus and San Jose are contained in Appendix C. These comments are strongly recommended for those readers desiring a more extensive discussion of how the Danish experience can be translated to municipalities in the United States.

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APPENDIX A -- TECHNOLOGY EXCHANGE PARTICIPANTS

- Participating Organizations
- Participating Individuals

TECHNOLOGY EXCHANGE PARTICIPANTS

Participating Organizations

The Danish study visit and the two following workshops in the United States were organized and staffed by the Energy Task Force of the Urban Consortium and Public Technology, Inc., from the United States, and by the Danish Board of District Heating and its member organizations in Denmark. A brief description of each of these organizations follows.

The Energy Task Force of the Urban Consortium

The Energy Task Force of the Urban Consortium is an organization with the formal mission to develop, apply and transfer practical technologies and innovative management techniques that aid effective energy management in America's cities and counties. With a membership composed of representatives selected from the 30 largest cities and 13 of the largest counties in the United States, the Energy Task Force designs annual work programs for applied research and technology transfer to improve the mix and efficiency of energy use both in local government operations and for the community as a whole. The city and county members of the Energy Task Force have maintained a continuing effort to support district heating and cooling in America's major urban centers. The U.S. municipal team was chosen from the membership of the Urban Consortium Energy Task Force.

Public Technology, Inc.

Based in Washington, DC, Public Technology, Inc., (PTI) is a non-profit organization that helps local governments throughout North America cut costs and improve public services through the practical use of technology and management systems. With programs organized in eight functional areas ranging from energy management to information technology, PTI serves as the technical arm of the International City Management Association and the National League of Cities. Acting as the secretariat of the Urban Consortium and its Energy Task Force, PTI provides both technical assistance and technology transfer services to its city and county members.

Danish Board of District Heating

The Danish Board of District Heating (DBDH) is a non-profit trade organization headquartered in Odense, Denmark, that represents Danish consulting engineers, contractors, researchers and manufacturers involved in district heating and related systems applications. The collective expertise of the members of the DBDH is largely responsible for the success and the continuing development of district heating in a country generally recognized as a world leader in its acceptance and use on a national scale.

Participating Individuals

Participants for the Danish study visit of August 19-23, 1985, consisted of municipal, private and federal representatives from the United States, and members of the Danish Board of District Heating.

The United States Team

The United States team consisted of municipal staff representatives from five major cities involved in district heating and/or cogeneration projects, representatives from three private organizations involved in these projects, and staff from the supporting organizations of USDOE and PTI.

- Municipal Staff Representatives:

  John K. Burge
Director
Special Facilities
Kansas City, MO

  David Rubin
Program Manager
Public Utilities
San Francisco, CA

  Richard Davis
DH Coordinator
Strategic Planning
Columbus, OH

  Rita Norton
Manager
Energy Programs
San Jose, CA

  Eugene Duffy
Deputy CAO
Atlanta, GA

- Private Representatives:

  Dr. Margaret Drake
National Geothermal
Columbus, OH

  Steven Schiller
Impell Corp.
Oakland, CA

  Gregory Conner
Atlanta Gas Co.
Atlanta, GA

- Support Organization Representatives:

  Allen Kennedy
Manager
Community Systems
USDOE/Argonne

  Richard Zelinski
Director of Research
Public Technology, Inc.
Washington, DC

Danish Board of District Heating

Representatives from the Danish Board of District Heating included managers and technical staff from both municipalities and private organizations in Denmark. Key individuals who participated in both the Denmark and United States portions of this exchange included:

Barry Shance
General Manager
Danpower, USA
Arlington, VA

Mogens Larsen
Chairman
DBDH
Odense, DK

Lennart Larson
Vice-Mayor
Odense, DK

Danish Board of District Heating (Cont'd)

Kim D. Trojberg B. H. Rasmussen Copenhagen, DK	J. Hebo Nielsen Cowiconsult Virum, DK	Eric Rasmussen DBDH Odense, DK
Gert Christensen ISS Electronics Skovlunde, DK	Jens Madsen I. C. Moller Fredericia, DK	Ebbe Clausen Pasilic Therm Kolding, DK

APPENDIX B -- PRE-VISIT PARTICIPANT QUESTIONS

- City of Columbus -- Richard Davis, Strategic Planning
- City of San Francisco -- David Rubin, Energy Bureau
- City of San Jose -- Rita Norton, Energy Programs Manager
- City of Atlanta -- Eugene Duffy, Deputy CAO

MEMORANDUM

TO: Rich Zelinski

FROM: Rich Davis

DATE: July 12, 1985

SUBJECT: Key Questions and District Heating Issues

The following issues/questions occur to me as the most important I would like to try to answer as a result of the proposed trip to Denmark.

(1) Conditions Favoring District Heating Development

One of the basic issues that keeps recurring in our research and discussions regarding district heating is that of comparability of the environment for district heating between Denmark and the U.S. No one to my knowledge has done a good study of the prevailing conditions--economic, political, financial and managerial--that support the development of district heating in Denmark (and by inference in the other Scandinavian countries) and which may or may not be duplicated in the environment of U.S. cities. The emphasis here is not on the technology--against the adoption of which there are no inherent barriers--but on prevailing attitudes, conditions and practices which may or may not support the development of district heating.

During our visit to Denmark I want to explore as fully as possible these underlying conditions which may explain the relative success of district heating in Denmark and which indicate under what conditions district heating will become more established in the U.S.

(2) Marketing and Economics. Is there competitive marketing for district heating in Denmark, particularly toward new developments or buildings which could adopt one of several alternative fuel sources? Or does district heating have such a distinct price advantage that builders or developers will always favor district heating? Are the cost advantages short-term, long-term or both? (I.e., is there a heavier capital investment up front which is justified by long-term savings?) What kind of marketing approach is used?

Referring to attached cost curve graphs, in the case of Hedensted option c1 and also a, initial district heating costs are higher than for individual gas-fired systems, although long-run costs are lower. Does this require direct consumer subsidies? Are early subsidies financed by the District Heating Authority and then paid off with later years savings? (See attached graphs and charts) We are mainly interested here with the way in which district heating capital costs are passed on to consumers.

(3) Incentives. Does the government offer any incentive to builders/developers to adopt district heating or to encourage one kind of fuel use over another? What kind of incentives are there and how do they operate?

(4) Expansion. How are decisions made regarding expansion of existing district heating systems into new areas? Do district heating systems expand into areas where they compete with alternative systems such as gas? Or are there decisions on utility service for particular areas made by the government or a public board or heat planning board commission? If district heating systems expand into areas with existing heat sources, on what basis does competition take place?

(5) Municipal involvement/ownership issues. Does type of ownership or operation of Danish district heating systems help explain their success? To what extent are municipal governments involved in owning/operating/financing district heating systems? How crucial is municipal involvement to district heating success? What role do municipalities play in planning and promoting district heating systems?

(6) **Financing/Revenues.** How are Danish district heating systems financed? How are bonds paid off and costs recovered? How are rates set? Are district heating systems profitable to own/operate? Are any systems in Denmark run on a for-profit basis? What classes of consumers are favored? Are there cross-subsidies favoring certain consumer groups?

(7) **Environmental Controls.** What sort of environmental controls exist on coal-fired heat sources? What sort of boilers are used in densely-populated or environmentally sensitive areas? What kind of clean coal-burning technologies might be adapted to Ohio (high sulfur) coal—such as fluidized bed combustion?

(8) **Planning.** What is the relationship between the Act on Heat Supply (Sept. 1, 1979), The Ministry of Energy, the Energy Control Board, the Energy Administration Agency, and Municipal Heat Plans? As we understand it, the Act on Heat Supply mandates the formulation of Municipal Heat Plans—by whom? What is the role of the Energy Control Board? How effective has this policy arrangement been as a real stimulus to district heating development? Any suggestions for the American scene? What is the heat supply planning process, and what suggestions would you have in that regard toward promoting American district heating development?

(9) **District Heating and Development.** Is district heating consciously used by planners as a development tool—i.e. to support industrial parks, to assist in revitalization of older areas, or to help attract industries or businesses to certain areas within cities? If so, how?

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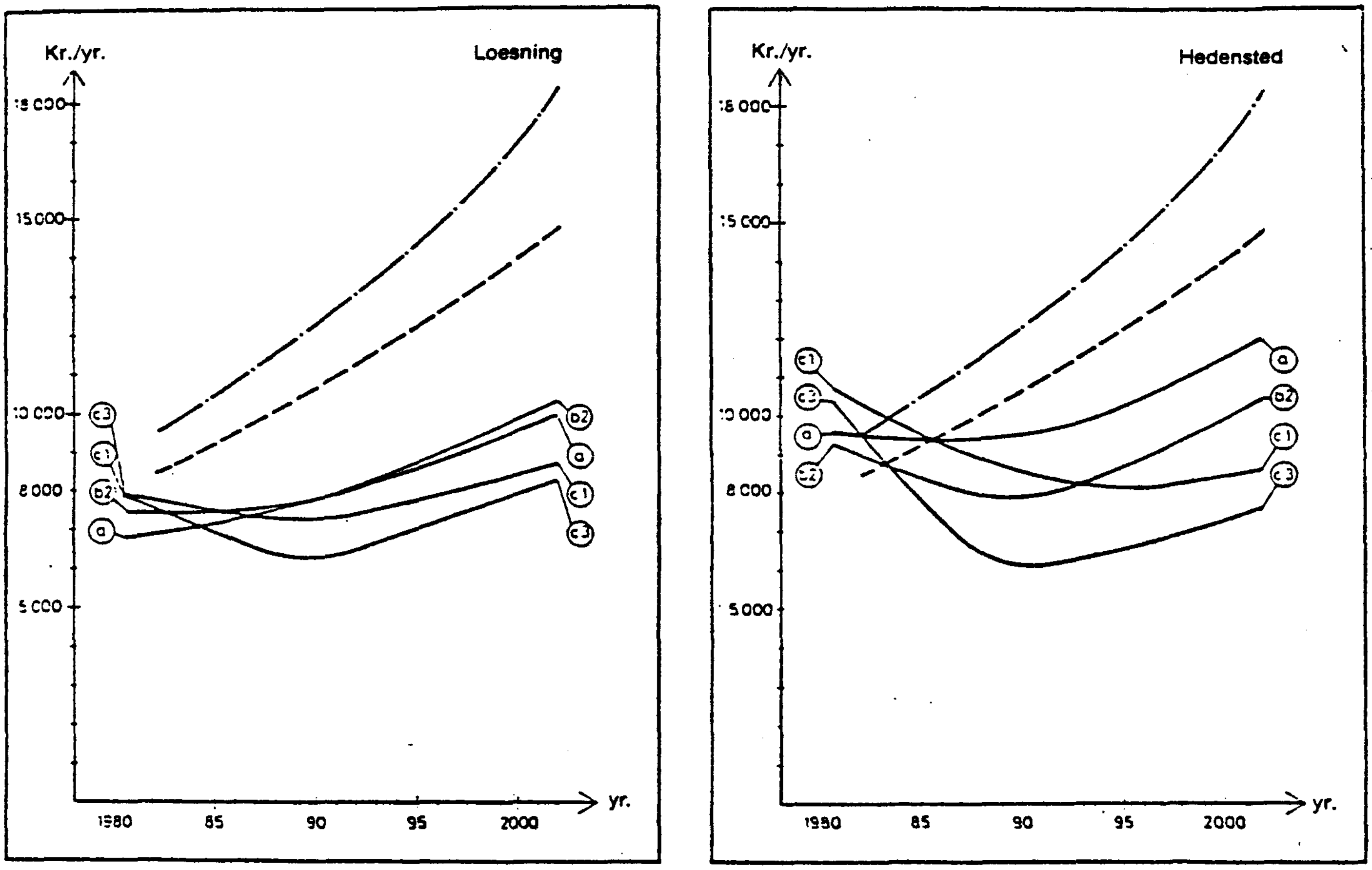

Fig. 2. Development tendency in consumer costs.

LEGEND

District Heating

Alternative no.

Individual natural gas

Individual gas-oil

of the Energy Control Board, a general natural gas price could not be fixed which could be used in Heat Planning in the other council districts.

THE COUNTRY CAN BE DIVIDED

An evaluation of whether a given area ought to be supplied with individual natural gas must therefore be made on the basis of a priority rating. The priority rating is defined as the investments in the natural gas distribution system divided by the expected natural gas consumption. In this way, the whole of the country can be divided into areas, each with their own ratings, and thus a measure of the areas' »suitability« for natural gas supply will be obtained.

With regard to a district heating supply of a given area, the evaluation can be made on the basis of a calculation of the present value of the project, as the whole basis is available here for a calculation of the total costs for a supply with district heating, in relation to a continuation of the existing supply (the reference).

In the calculations for some of the alternatives in the Hedensted project, the present district heating area has been extended by some 250 dwellings, of which 200 will be connected to district heating. In alternative c1 - coalfired CHP - the increase of the socio-economic present value was hereby calculated to approx. 5 million Dkr. This means that society saves about 2500 Dkr. per year per house in 1980-kroner values or roughly 20% of the socio-economic costs of heat supply.

It must therefore be expected that conflicts will occur in quite a number of municipalities with regard to area-border placement. On the one hand, the Council wants to extend district heating, because it means the lowest costs for the consumers - and also for society in general. On the other hand, the central authorities want a development with natural gas to secure a market for the sale of natural gas.

How this conflict is to be solved is not yet known. □

The interest of the individual consumer in changing from individual gas-oil firing to a collective supply can be extremely decisive for the result of economic calculations. In order to pinpoint the consequences, three of the alternatives were calculated with three different conversion progress schedules.
The other alternatives were calculated only with conversion in terms of natural progress.
The economics of three main supply systems a, b and c were calculated.
Alternative a is based on as great a supply coverage as possible by natural gas. This means that Hedensted District Heating uses natural gas as its fuel. Loesning District Heating has more than half of its energy requirement covered by industrial waste heat and uses fuel oil for the rest. The district heating supply area includes the existing built-up areas extended to an 100% connection of the possible space heating demand (ie. all individual consumers, apart from consumers with electric heating and similar).
In alternative b the possibilities are investigated of increasing the volume of surplus heat to the district heating supply. Three investigations have been carried out under this alternative.

THE ALTERNATIVES
In alternative b1, the district heating areas in Hedensted and Loesning, described in alternative a, are interconnected with a transmission main. The maximum amount of surplus heat available in alternative a is increased by 25%, by means of a heat pump system, as more surplus heat was found than was shown in the survey. Both measures increase the utlized surplus heat.
Alternative b2 has the same supply conditions as alternative b1, however, the district heating area is increased by 250 single-family houses. The purpose of this is partly to see what happens when district heating replaces individual natural gas, and partly to see how much the surplus heat utilization can be increased during the Summer period.
Alternative b3 corresponds to alternative a, apart from the fact that a heat accumulator is installed in the industrial plant, which is closed at weekends, in order to cover week-end consumption in the Summer halfyear.
In alternative c, the possibilities are investigated of establishing a CHP station or a coal-fired district heating station. The plant would function as the primary supply source and, together with the surplus heat, be able to cover 70-80% of the required demand. The remaining heat demand would be covered by the existing district heating stations, which would function as peak load and standby plant. This means that less than 10% of the annual heat consumption would be produced with fuel oil at the existing plants, the rest being produced with coal or natural gas, or coming from surplus heat. A prerequisite of course, is that a transmission main be established between the two district heating systems.
Alternative c1 consists of a coal fired CHP station with back-pressure plant.
Alternative c2 consists of a natural gas fired CHP station with gas turbine plant.
Alternative c3 consists of a coal fired district heating station with chain-grate stokers.
Economic calculations were made at three levels: social, company and consumer levels. The result of these economic calculations is shown in Table 2.

Table 2.

Supply Alt./	Conversion progress	Socio-economy (for all partial-plan areas) Present val. (Mill. kr.)	Internal (%) interest	Company economy Average cost for total planning period in 1980 kr. per GJ (incl. taxes) Hedensted D.H.	Loesning D.H.	Consumer economy (incl. operation of boiler room inst.) Average price for total planning period in 1980-kr. per year (incl. VAT and duty) Hedensted D.H. Heat dem. 100 GJ/year	Heat dem. 70 GJ/year	Loesning D.H. Heat dem. 100 GJ/year	Heat dem 70 GJ/year
	slow	101	59						
a	natural	109	49	85	66	10.300	7.700	8.100	6.200
	fast	110	44						
b.1	natural	110	40						
	slow	103	49						
b.2	natural	111	40	74	69	9.100	6.800	8.500	6.400
	fast	112	40						
b.3	natural	109	46						
	slow	113	26						
c.1	natural	135	29	75	63	9.200	6.900	7.800	5.900
	fast	138	29						
c.2	natural	100	35						
c.3	natural	116	39	63	59	7.700	5.900	7.300	5.600
	Individual natural gas supply					12.400	9.100	12.400	9.100
	Reference plan (gas-oil operation)					14.700	10.600	14.700	10.600

City and County of San Francisco

Public Utilities Commission
Bureau of Energy Conservation

MEMORANDUM

July 15, 1985

TO: Richard Zelinski

FROM: David Rubin

SUBJECT: Questions for Danish District Heating Site Visits

1) What new techniques are available for minimizing installation/replacement of distribution mains in dense, congested urban areas, particularly where a number of utility lines exist?

2) What are the general rules/cautions/constraints in developing a hybrid district heating system? What considerations govern the steam/hot water interface? What change in temperature can be expected across the heat exchanger? Can you develop a steam system with plans for an ultimate conversion to hot water?

3) How difficult is it to convert an end user currently designed for steam to utilize hot water?

4) For large integrated networks, how do you size the centralized, base load generating plants vis-a-vis the localized peak plants? E.g. should the centralized plant be capable of carrying 60% of the total peak, with the localized plants capable of providing the additional 40%? Is any difficulty encountered in mixing thermal sources of different temperatures?

5) What new distribution materials are available? Insulation materials? Is there any penalty for installing excess distribution capacity other than the higher incremental material costs?

6) How are costs apportioned to thermal and electrical energy from a cogeneration system?

7) What end user incentives/regulations for connection has been found to be the most useful and desirable? At what point in the building/planning approval construction process are you best able to "market" district heating? What is your most effective leverage?

(415) 864-6915

San Francisco 94102

8) How extensive is district cooling? How is centralized cooling economically justified, since electricity is the primary "generation" source, and is available at more-or-less equivalent prices at the central plant and end user? Are there other compelling non-economic arguments in favor of district cooling?

9) Are heat pumps integrated into low-to-medium temperature hot water systems? What are some of the sizing and operating parameters?

10) How extensively is thermal storage integrated into district heating/cooling systems? What are the general design and operating rules of thumb?

11) What is your most optimal/desirable customer mix, in terms of industrial, commercial, retail, institutional and residential end users?

12) How extensive is the use of computers in the operation and control of the generation and distribution systems?

DER:lsm

Memorandum

August 2, 1985

To: Richard Zelinski

From: Rita Norton, San Jose

Subj: Questions for Danish DH Visit

1) What techniques are used to accomodate dual fuel systems (example: natural gas & solid waste combustion)? This question especiall related to procedures for switch-over, using the same piping, for boiler and feed water systems.

2) What procedures are commonly used for customer billing? What metering techniques and what units are used to base billings? Are there "take-or-pay" provisions? How are revenues actually collected? What costs are incurred for metering and billing?

3) For system maintenance -- what type of system maintenance is a normal practice; at what intervals; with what required skills; and at what general cost?

4) How do monitoring and control systems accomodate variations in thermal demand, especially for diurnal peaking? Are demand controls manual or automated, and what type of equipment is used?

5) What are usual provisions for emergency back-up? Are there specific techniques used to meet high thermal demands, peaking and shut-down events?

6) Additional questions not directly related to District Heating:

   - How is hazardous waste managed in Denmark?

   - What are normal practices for water and wastewater management?

   - What energy efficiency standards are used for buildings?

Memorandum

August 6, 1985

Atlanta Questions for Danish Visit

1) How are market and economic analyses used in Denmark to guide decisions for the construction or rehabilitation of a DH system? Are there standard procedures and simple guidelines to justify a given level of investment?

2) What ownership patterns have been found most successful? Is ownership a function of the customer base, the type of facility, or the size of the facility?

3) What marketing procedures are used to encourage potential users to connect? Does a DH system tend to encourage the location of new business and industry within its service area?

4) Where do energy utilities (especially those that provide natural gas) "fit" in the Danish DH procedures; i.e., as suppliers, owners, operators, etc.?

5) How are retrofit or conversion costs for end-user systems calculated? Are these costs paid by an individual user, or are costs tied into the rate base or other continuing charges for the system?

6) What experience does the DBDH have for thermal plant and distribution system rehabilitation? This question especially related to steam systems that have been underutilized for a period of time.

7) What skills are essential to operate, maintain and market a DH system? This question especially related to successful start-up of a system when potential users may not have a sound understanding of what district heating offers.

APPENDIX C -- POST VISIT PARTICIPANT REACTIONS

- City of Columbus -- Richard Davis, Strategic Planning
- City of San Francisco -- David Rubin, Energy Bureau
- City of San Jose -- Rita Norton, Energy Programs Manager

Remarks to the Danish Board of District Heating and Guests* on October 28, 1985

By Richard C. Davis, District Heating Coordinator
Division of Strategic Planning
City of Columbus

(Introduction)

Let me tell you and show you a few things that I learned about Denmark. Denmark is a small country on the north coast of Europe, population about 5 million. It has always been a sea-going country: much of Denmark consists of islands, some large, some small. Once you are out of the big city (about one fifth of all Danes live in Copenhagen), you find a remarkably pastoral countryside and many well-preserved Renaissance castles like this one (slide # ____).

Questions

When I traveled to Denmark in August there were basically three questions I wanted to answer:

(1) Why is district heating so successful in Denmark? Denmark has 400 district heating systems which serve about 40 percent of the country's housing. Certainly Denmark has plenty of cold weather which makes district heating attractive, but we have cold weather here, too. Denmark has much more district heating per inhabitant than even Sweden and Finland. Why?

(2) What is the economic and political environment in Denmark that supports district heating? Several of our group who went to Denmark were engineers and were interested in district heating technologies and how they work. This was interesting to me also--but as a planner I tend to look for the answers in economics and politics. The question is, how do the economics of Danish district heating compare with the U.S.? Are the economics based on factors like fuel prices that are totally different between Denmark and the U.S.? And what would it take to create a favorable political environment for district heating in the U.S., especially in Columbus, Ohio?

(3) The third question, and an obvious one to try to answer, was whether any of the successful aspects of the Danish district heating experience could be transfered or replicated in Columbus? Obviously I am more interested in

*accompanied by slides--see numbers at left of page those features that we could bring back with us, than those features that are absolutely unique to Denmark.

Lessons

Let me get right to the lessons I learned.

First, as Mogens Larsen told us, SIMPLICITY and ADEQUACY are the guiding principles of Danish district heating. That is to say, you build a district heating system that is adequate to the job at hand. You don't oversize it, so you keep down costs. But you design it in such a way that you can expand when your revenues begin to come in and the economics improve. The Danish preference for hot water and lower pressure systems fits in (I believe) with these principles of simplicity and adequacy.

Secondly, there are price differences in boiler fuels between Denmark and the U.S. But I'm not sure those differences matter very much in comparing the viability of Danish vs. U.S. district heating. Everywhere I went in Denmark, I kept asking for the alternative gas or fuel oil prices. I was thinking that perhaps gas or oil were so expensive in relation to the U.S. market, that the price factor might explain the real attractiveness of district heating in Denmark. But the real question is not whether gas or oil prices differ between the U.S. and Denmark. The only important question is what is the difference in price between your cheapest fuel (coal) and the available alternatives (gas or oil)? You see, coal is also more expensive in Denmark than it is in the United States. And the difference between coal and gas prices in Denmark is probably the same, or nearly the same, as in the U.S. It is the relative fuel prices that matter and not the absolute prices, in determining the viability of district heating.

In response to my question about the relative price competitiveness of district heating in Denmark, HML engineers prepared a comparison of consumer costs for different types of home heating systems in Denmark, with district heating connections and without. (See table). In this comparison, the most expensive alternative is that of a "heat only" oil-fired district heating system; the least expensive alternative is a combined heat and power system, coal-fired, which serves Odense consumers.

This leads to the third lesson. A district heating system has to be based on your cheapest fuel. When district heating systems in Denmark began to expand in the 50's and 60's, the cheap fuel was heavy oil. In 1970 heavy fuel oil in Denmark was about $10 per ton. Today it is $180 per ton. The cheapest fuels now are coal or trash. This (slide) is the big trash-burning incinerator of Vestforbraendig. It is the

Annual Consumer Cost Comparisons: District Heating Versus Individual Central Heating in Denmark

		Investments	Cost of Financing	Standing Charge	Heat Consumption Charge	Metering Electric Service, Etc.	Total	Cost Per Million BTUs	
		D. Kr.	D. Kr.	D. Kr.	D. Kr.	D. Kr.	D. Kr.	D. Kr.	(Index)
District Heating	Combined heat and power coal-fired (Odense)	23,750	3,180	1,283	2,530	214	7,207	115.7	57%
	"Heat Only" coal-fired (Assens)	13,420	1,797	1,884	5,508	134	9,323	148.9	73%
	"Heat Only" oil-fired (Elborg)	11,130	1,490	2,596	8,540	73	12,699	202.9	110%
Individual Central Heating	Oil	23,180	3,103	-	8,494	1,100	12,697	202.8	100%
	Natural gas	16,000	2,142	-	7,482	1,100	10,724	171.3	84%
	Electric heated								

Single family detached house, existing buildings
- gross area: 130 sq. meters
- annual heat consumption: 62.6 million BTUs

D. Kr. = Danish Kroner
Exchange Rate (11-6-85): $1.00 U.S. = 9.44 Kr.

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largest in northern Europe with a 60 MW thermal capacity, and it ties into the Copenhagen district heating system.

The fourth lesson is that there is definitely a lot more centralized energy planning in Denmark than in the U.S.--and by that I mean centralized planning at the local level as well as at the national level. Denmark is the first country in the world to begin total planning of its energy supply system. Each county and municipality is requered to submit a detailed heat plan for approval by the Ministry of Energy.

This kind of centralized planning <u>in itself</u> does not explain the success of district heating systems in Denmark. Most of the district heating systems were already in place before centralized planning went into effect in 1979. And <u>don't</u> think that district heating works so well in Denmark because it is heavily subsidized by government. In fact, it is a requirement that district heating systems must pay their own way and pay off their loans.

Fifth, I found out that weather and climate are certainly very different between Denmark and the U.S. I left Denmark in a cool 60-70 degrees F and arrived back in Columbus to 90 degree weather. We have something like 5400 heating degree days in Columbus as opposed to over 8000 in Copenhagen--which is similar, incidentally, to the climate of Minneapolis. Again, climate may contribute to the economic viability of district heating in Denmark but does not mean that district heating systems will not work in a more moderate setting. Preliminary economic analysis suggests that district heating can be viable here depending on several factors--primarily on the cost of your base-load fuel. Also, as Barry Shance points out, a more moderate climate may actually be an advantage in designing district heating systems, because your peak load is smaller, meaning that up-front infrastructure costs can be minimized. Obviously if you can use a system which also supports district cooling, your economics will look even more favorable--the system will pay for itself throughout more of the year. That is why I am interested in learning more from our Danish friends about the potential for district cooling.

So economic features are definitely important in explaining why district heating works in Denmark. But unless you rely on the viewpoint of economic determinism, which I don't, you can't explain district heating success by economics alone. After visiting Denmark, I have to conclude that people's attitudes are also very important. After all, this is a country where bicycling is an accepted means of getting to work, where trash recycling is a common practice, and where people work to get the most out of the energy they use. Engineers and architects are aware of the potential for conservation and district heating, and they consider that potential when they site and design buildings. Power plants are built to provide combined heat and power. Economics are important, but ideas are powerful too. People in Denmark realize the economic facts of life, but they also have a vision which helps them make the best use of limited resources.

A final important lesson from the Danish district heating experience is that heavy density of consumer load is not always necessary for a district heating system to make economic sense.

District Heating in Odense

This is Odense, Denmark's third largest city--better known as the birthplace of Hans Christian Andersen. Odense is a city of 170,000 people, in an area of about 131 square miles. It may surprise you to know that Columbus--as spread out as it is--is still a much denser city than Odense. Odense has about 1300 people per square mile, while Columbus has over 3000 people per square mile.

Nevertheless, Odense has one of the most successful district heating systems in Europe, with 1200 miles of pipe and a connected design load of 1100 megawatts. About 95 percent of the population is connected to the system. And this is in a city where more than 60 percent of all homes are single-family houses--for this reason Odense is known as the "biggest village in Denmark."

Let's take a closer look at Odense and see what lessons we might be able to apply to Columbus.

Odense has had a district heating system since 1929. It has always been a hot water system, supplied at first from a combined heat and power plant near the city center. Major expansion of the system was only possible in 1953, when the giant Fynsverket power plant began operations. Now this plant is a big one--about 7 to 800 MW thermal capacity--and it is coal-fired. Its distance from the center of Odense? It's four or five kilometers away from the center of town--but the network really extends much further than that. These pipes (see slide #   ) are being laid to connect greenhouses and homes in suburbs of Odense.

The greenhouses are furthest away--about 12 to 14 miles south of the Fynsverket power plant!

How did the network become so extensive? Back in the 1960's, several suburbs of Odense had also developed their own independent district heating systems. These were built to serve neighborhoods from oil-fired boiler stations like this one in Mogens Larsen's neighborhood of Naesby. This station serves about 2000 single-family homes. At that time--back in the 60's--oil district heating systems made sense because the heavy oil used here was cheaper than the light oil people used for the boilers in their own homes. People building homes at the time also benefitted because they could save the space they would have neeeded for an individual heating system.

There were also a couple of cooperatively-owned systems near Odense, including a district heating system owned by several greenhouse enterprises.

During the 1970's these independent systems were tied into the larger Odense network. The timing was right, because with the oil price shocks, coal was certainly a much cheaper baseload fuel.

The existing oil-fired stations have become back-up and peaking stations to support the overall system. Currently the Fynsverket power plant supplies about 90 percent of the network's need, with 10 percent from these smaller peaking plants.

What are the savings to the homeowner? Currently, the average price of district heat for someone on the Odense system is about $3.25 per MCF (as near as I can figure)--a savings of about 40 to 50 percent over the next available alternative. With capital investment in the system largely amortized, the system shows an internal rate of return for the Municipality of 25 to 37 percent. You can see why just about everybody in Odense is on the system!

I hope that people from Columbus have noticed the parallels that exist between our city and the City of Odense. Here we have two cities of relatively low density, both with large numbers of single-family houses, each with a power plant within range of the city center. Maybe we can go further and say that both cities are looking toward the future; both cities are trying to preserve the best of the past; both are trying to make the best use of their native talents and resources.

I think you can see why we have a lot to learn from Denmark, and why we in Columbus are trying to test the Danish approach to district heating to see if we can apply it here. The Danish district heating approach, based on principles of

--simplicity and adequacy

--using your cheapest fuel

--starting small, creating revenues, then expanding

--these ideas make sense to us in Columbus. We are interested in the idea of district heating--not just as an atractive technology, but as a development tool. Can district heating--or more specifically the availability of a cheap and reliable energy source--help target investment into our downtown and riverfront areas? Can district heating help rejuvenate our older residential areas? Can district heating help us create a vision to guide our future development? These are questions we want to try to answer with the help of the District Heating Task Force.

This (slide) is the Dybbol Mill, which stands near the Danish border as a monument and symbol to Danish independence and resistance. The Mill was twice destroyed during fighting in the 19th century but has been rebuilt each time. I thought it very interesting, after my tour of Danish district heating facilities, that this wind machine should stand as a symbol of Denmark's national resilience.

Perhaps, I thought, in a similar way, the combined heat and power plant can be seen as today's symbol of Danish independence: of Danish determination to control their own future, to make the best use of their very limited natural resources but very extensive intellectual and technological resources. I think this is the major lesson I brought back from Denmark and I thank you for allowing me to share it with you today.

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DISTRICT HEATING INTEGRATION AND EXPANSION IN SAN FRANCISCO

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DISTRICT HEATING INTEGRATION AND EXPANSION IN SAN FRANCISCO

This paper discusses the combined efforts of the City and County of San Francisco, Pacific Gas and Electric Company, and the Danish/American joint venture consulting firm of Ammann & Whitney - Danpower, Inc. in investigating the integration of the City and PGandE district heating systems, and the expansion of PGandE's system into areas of new development in downtown San Francisco. The applicability of the Danish approach to district heating is discussed within this context.

Historical Overview

District heating has been a part of San Francisco's energy supply picture since the early 1900's. Prior to 1911, three electric companies utilized the exhaust heat from steam electric plants to serve buildings in downtown San Francisco. In 1911, Pacific Gas and Electric Company entered the district heating business through the generation of steam by single purpose boilers. In 1915, the three steam electric plants were purchased by the Great Western Power Company, which in turn was acquired by PGandE in 1930.

In 1915, the City and County of San Francisco constructed its own central heating system, also based on steam, to serve several municipal buildings located in the Civic Center Plaza, immediately west of downtown. This system was later expanded to serve additional City buildings, bringing the total to seven (7).

These two systems have survived the ensuing decades, albeit at a combined loss of efficiency, customer base and service territory. The PGandE system has experienced a loss of customers from a high of 725 in 1933, to a low of approximately 200 in 1983 (this, however, occured during a period when the sales increased by approximately 25%). Despite the prompt and reliable service offered by this system, a number of factors combine to result in an overall system efficiency of approximately 60%. Included are heat losses through poorly-insulated mains, heat production through single-purpose natural gas boilers, and the lack of a condensate return.

The City system has similarly been subjected to several decades of aging, wear and tear, and escalating energy costs. The only response taken to this degradation has been routine repair to boilers and delivery mains. Cost-effective measures to reduce energy consumption (e.g. main reinsulation and valve replacement) have not been pursued.

Phase I Study

In 1983, the City and PGandE independently and cooperatively took steps to evaluate the viability of district heating in San Francisco. PGandE performed its own internal audit, and participated in a City-wide evaluation conducted by a Mayoral-appointed advisory committee. These individual investigations concluded that district heating represents an important energy supply option for San Francisco, and recommended that specific steps be taken to ensure that service is maintained as reliably, efficiently and economically as possible. Included as recommendations for both the PGandE and City systems was the establishment of preventive maintenance programs; replacement, where economic, of insulated main for sections where insulation had worn-away; and detailed investigation of the integration of cogeneration systems to replace single-purpose boilers as heat generators[1]. Additional recommendations for the PGandE system included abandonment of uneconomic portions of the system; in-fill of customers within the existing service territory; and system expansion to serve new customers within high growth areas.

Influenced by the Phase I investigation, PGandE decided to fortify its district heating business by creating a dedicated district heating department, and by actively pursuing a cogeneration strategy. The City, in cooperation with PGandE and the Danish/American joint venture consulting firm of Ammann & Whitney - Danpower, applied to the Federal Department of Housing and Urban Development for funding for further investigation of two specific options: retirement of the 70-year old City boilers and interconnection of the City system with that of PGandE; and the expansion of the PGandE system into new designated growth areas.

<u>Overview of Phase II Study</u>

The consultants conducted an economic analysis which demonstrates that, at current PGandE steam rates, an intertie between the City and PGandE systems would provide benefits to both parties. This analysis assumes that a 2500 foot interconnect main would be installed from the PGandE boiler facility to the current City boiler site. Under discussion between the two parties is financing and ownership responsibility for the interconnect main, what rates the City will pay for steam, and whether the City or PGandE will own and maintain the City loop.

The remainder of this discussion will focus on the analysis of the expansion of the PGandE system into new growth areas immediately adjacent to the central heat plant. This analysis has allowed the consultants to apply in San Francisco the advanced planning, design and engineering expertise which has contributed to Denmark's current position as a world leader in district heating.

Specific sections of San Francisco have been designated as areas of new, high density development. Extensive experience throughout the world concludes that such areas are best suited for district heating development, since a large load can be served at minimal cost of distribution installation. Because the distribution system represents the most expensive system component, it is important to minimize its impact, and to spread these costs over as large of a customer base as possible. In San Francisco, this is imperative for the success of district heating, since the high level of utilities located under the streets contribute to an installed main cost of approximately $600 to $700 per lineal foot.

Recent district heating experience has also demonstrated that the best heat transport medium for non-industrial process loads is through low-to-medium temperature (less than 250^{o} F) hot water. Installation costs are reduced, and distribution efficiency is improved. Mains delivering hot water in this temperature range can be insulated in the factory using inexpensive polyuerathane foam, and covered by a polyethylene casing (as opposed to more expensive steel). Installation is simpler and less costly, due to lighter weight materials. Moreover, thermal losses in the distribution of heat are reduced. Since most buildings in or near downtown San Francisco require heat at or below 250° F, customer needs can be adequately supplied.

Danish District Heating Success

It is important, at this point, to discuss the appropriateness of "Danish-style" district heating in the United States. District heating has fared with much success in Denmark. According to the Danish Board of District Heating, more than 40% of the homes in Denmark are connected to a district heating system; approximately 50% of the heat demand in Denmark is expected to be served by a district heating system in the near future. In the United States, however, most systems have experienced a decline in sales and customer base[2], with some owners abandoning their systems rather than investing in costly upgrading. Technical reasons notwithstanding, there are numerous non-technical reasons cited for this disparity between district heating growth in Denmark (and Europe in general) and the U.S. Included are the following:

Fuel Costs. The cost differential between fuels for district heating and those for the conventional on-site alternative is greater in Denmark than in the U.S. This is likely the primary driving force behind the success of Danish district heating. The cost of fuel for on-site heating (e.g. fuel oil or natural gas) is generally twice that of U.S. prices. It is therefore much higher than the cost of cogenerated or waste-generated heat. As a result, customers are naturally attracted to a heat supply which is less expensive, safer and easier to handle than the alternative. This differential is much more pronounced in a mature system, in which the percentage of cogenerated or waste-generated heat can be as high as 95%. In developing systems, single purpose boilers can still offer economic heat through the use of lower-grade, less expensive fuel oil or coal.

Energy Legislation. The Heat Supply Act of 1978 was enacted to promote the most economic use of energy for heating buildings, and to reduce Denmark's dependence on foreign oil. These aims are to be achieved by conversion from individual to collective heat supply when it is economic to do so. The Act requires that municipalities and City Councils develop and justify all heat supply plans. The plans must demonstrate to the Minister of Energy that systems to be implemented are viable and in compliance with overall energy policy. Moreover, the organizational framework for implementation and operation, financing and pricing policy must be described.

Moreover, even though it is rarely exercised, a provision of the Act enables municipalities to require building owners to switch heat sources when the national interest will be served. However, few municipalities have exercised this authority due to its political sensitivity.

Municipal and Cooperative Ownership. Onwers of the district heating systems in Denmark are, largely, municipalities and cooperatives. The major advantage of municipal ownership lies with its natural marketing advantage, in that like most municipal services, customers come to expect and look for the district heating system when obtaining a building permit.

Planning of Buildings. The construction of new buildings, and consequently, the development of new loads is largely in conformance with multi-year development plans. This assists district heating system owners in forecasting load growth, and developing system expansion plans accordingly. Thus, expenditures in the system can be timed to coincide with actual revenues, thereby avoiding a situation in which installed capital is not economically employed for several years, or in some cases, never realizes its full capacity.

Mixed Use Development. Land use development in Denmark follows more of an integrated/mixed-use pattern than in the U.S. This allows for the development of heat demands which represent a well balanced combination of commercial, residential and industrial users (the concept of "diversity"), and for the siting of waste-to-energy and cogeneration plants within sufficient proximity to economically serve these loads. In such a system, heat can be delivered much more economically, and installed generation and distribution capacity can be utilized much more efficiently.

"Tradition". District heating in Denmark has been developed to the point where it is the "incumbent" heat source, i.e. building owners are accustomed to connecting to a district heating system when it is available. Therefore, an alternative heat supply has the burden of proof in demonstrating that it is more economic. This is entirely opposite to the U.S. situation, where building owners will continue with business as usual, unless district heating is able to make a very strong case for itself.

Individually, the above differences are not sufficient cause for the success of Danish district heating and the lack of this success in the U.S. However, collectively, and in combination with the cost-cutting technologies developed in Denmark, these elements begin to offer fertile grounds for the growth of district heating.

San Francisco Expansion Area Study

The approach employed by the project team in analyzing and planning district heating expansion in San Francisco relies upon experience gained in both Danish and U.S. district heating planning. The following are the core steps of the study:

1. Project Heat Demand. First, the area to be served is analyzed with respect to existing buildings as well as potential building growth. The amount of growth for the study area should be projected as specifically as possible, i.e. on a site-by-site basis. These estimates can be translated into heat demand projections by applying approximate peak and average annual thermal demand factors (expressed in Btu's/gsf/hr and Btu's/gsf/yr, respectively).

2. Identify Potential Heat Sources. Existing or potential heat sources can then be identified, and the costs of supplying heat from these sources estimated. An important consideration is the timing of the heat sources vis-a-vis the load, as heat sources must be available when the load is developed. Otherwise, an opportunity to serve a potential anchor load is lost, and it is much more difficult to attract a customer once an on-site plant has been installed.

3. Link Heat Sources and Demand. Once the potential heat loads and heat sources have been identified, a preliminary design of a transmission and distribution network which links the sources with the demand can be formulated. Danish experience indicates that systems should develop incrementally. This generally means that decentralized load centers should be served by decentralized heat sources, with the various "micro-systems" eventually interconnected when it is economically justified. In Denmark, small systems are intially developed around single purpose boiler stations. At a later time, these "satellite" stations are interconnected to one or more centralized cogeneration or waste-to-energy facilities, supplying lower cost heat. The decentralized boiler plants are maintained for peaking and reliability purposes. The end result is typically a system in which 60% of the peak, but greater than 90% of the annual demand is supplied by inexpensive waste heat.

   This approach offers many advantages. First, small decentralized heat sources can be developed relatively quickly. They can thus "capture" anchor customers, the connection of whom is often critical to successful district heating system development. Second, capital is expended in step with the generation of revenue, and the risk associated with system development is reduced.

4. Perform Preliminary Economic Analysis. Once a preliminary design of the system has been developed, the cost of service can be estimated based on investment and operating costs. The former includes generation and distribution equipment. The latter includes fuel and operation and maintenance costs. Once estimated, these costs can be compared with those of on-site heating to determine if the central system is likely to attract customers. Depending upon the economically capturable load, engineering estimates of the transmission and distribution network can then be refined.

The final development/expansion plan should be comprehensive, but should also be sufficiently flexible as to allow for a wide range of potential load development scenarios, since this is likely to be the most variable part of the equation. Therefore, the San Francisco study will include a thirty-year expansion development plan, with directions for an annual review.

Status

To date, the analysis for the interconnection of the PGandE and City steam systems has been completed. This analysis indicates that the intertie should be undertaken. The City and PGandE are currently negotiating specific terms for the sale of steam from PGandE to the City.

The expansion analysis has advanced through the preliminary design stage. The costs of PGandE steam has been determined to be economic with hot water generated in on-site boilers. A preliminary distribution network and expansion plan is being developed for projected building growth within a 30 year time frame. As mentioned previously, the Danish experience with hot water has influenced the heat transfer medium selected for the expansion. However, PGandE's system is currently a steam-only system, and in order to meet the requirements of certain customers, the intial expansion may be steam, with sufficient flexibility allowed for the later conversion to hot water.

Notes

1 A subsequent evaluation conducted by the City concluded that cogeneration would not be a viable heat source to serve the reduced load resulting from a conservation program directed at the reinsulation of exposed mains.

2 According to the International District Heating and Cooling Association (IDHCA), reporting member companies have experienced a decline in sales of almost 50% from 1973 through 1983 (IDHCA Annual Statistics for 1983).

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REPORT OF THE 1985 ENERGY TASK FORCE TOUR OF DENMARK's INTEGRATED DISTRICT HEATING/COOLING PLANTS

Background

During the last several years, the City of San Jose has begun to study, evaluate and design district heating and cooling systems, primarily with cogeneration plants as the energy source. The interest in cogeneration has developed in six phases:

1981-82	Report of potential for cogeneration in the downtown, 1981, TERA & Associates, funded by the California Energy Commission and Pacific Gas & Electric Co. for the City of San Jose.
1983-	Feasibility of cogeneration in Convention Center Superblock, Syska & Hennessy; McOuat & Associates 1983-84; Redevelopment Agency.
1983	Waste-to-Energy Technical Assessment, 1984, conducted by U.S. Conference of Mayors.
1984	Feasibility of cogeneration for City/County Civic Center, 1984-85; Brown Vence & Associates; jointly funded City of San Jose and County of Santa Clara.
1985	Sizing and Financing Plan for City of San Jose Convention Center Superblock, 1985, Impell & Associates, funded by HUD & San Jose Redevelopment Agency.
1985	Planning for expansion of the downtown system and for commercial industrial energy parks in locations throughout the City.

There are three active current projects:

1) Convention Center Superblock - New Construction.

Currently, the Convention Center Superblock project is at a decision point for sizing and obtaining Redevelopment Agency financing. Recommended by staff is a central heating/cooling plant with a 1.5 MW cogeneration system. The estimated cost is $2.5 million with funds to be repaid from project revenues. This project will supply heating and cooling energy, as well as electricity, to the convention center, the City's main library and two adjacent hotels. The project has substantial economic benefits for the City and the hotels.

Comparisons between two cogeneration plant sizes of 750 kw and 1500 kw have been considered. In all, there are three configurations; 750 kw plant for the Convention Center only; 1500 kw for Convention Center, one hotel and Main Library; and 1500 kw for Convention Center, two hotels and Main Library. Either plant size is characterized with the same basic features: use of natural gas to drive a reciprocating engine generator to produce electricity on site, with the simultaneous recovery of the heat from the engine to heat the buildings and water and to produce cooled air. The smaller plant of 750 kw would service only the Convention Center. The larger plant of 1500 kw would service the needs of all the buildings on the superblock, including the Convention Center, Main Library and hotel(s).

The concept of applying the technical and economic advantages of cogeneration to the downtown plan is based on using the yield of dollar savings from cogeneration as an economic incentive to support Redevelopment objectives. Serving buildings with heating, cooling and electricity at a reduced cost from cogeneration is, in effect, an incentive offered by the City to locate in the downtown. The incentive for locating in the Redevelopment district as a result of operating or capital savings can be potentially very useful in implementing the City's community development objectives.

2) Civic Center Plant Project - Retrofit

This project involves a 2.6 MW plant to service the City and County office buildings and a new County Jail building located at the Civic Center Complex. The County is recommending a cogeneration system consisting of two 1300 kw reciprocating engines with waste heat recovery hot water boilers. The construction costs of the recommended system are approximately $3.6 million. The first year net savings by implementing the recommended system is $606,000.

3) Downtown Expanded System

Expansion of the Convention Center Superblock project to a downtown plan of cogeneration district heating/cooling system is being studied by the City and PG&E. Impell and Associates are reviewing cogeneration and district heating and cooling options. PG&E, the local public utility, has expressed interest in establishing a district heating and/or cooling service in the downtown.

The PG&E's preliminary review suggests that the downtown area, including the Convention Center might be better served by the introduction of an expanded district heating/cooling system. They have expressed belief that there might exist benefits to the City of San Jose, the downtown area and to PG&E with such an expanded system.

PG&E wishes to explore the district heating/cooling concept further. If the City concurs, PG&E will proceed with a study to determine the feasibility of an expanded district heating/cooling system in the San Jose downtown area.

What Was Learned

Lessons learned from the trip centered on Denmark's demonstration of the technical and economic viability of a variety of district heating systems. These include:

- o Very large hot water and steam distribution systems using waste heat from utility owned coal-fired heat and power plants (100+ MW)providing heat to medium-sized systems which in turn service industrial, commercial and residential uses.

- o Medium sized district heating systems with heat source that include waste-to-energy plants (60 MW), with peaking oil-fired boilers, providing hot water for industrial, commercial and residential use.

- o Small sized systems which service users that include single family residences, businesses and government buildings. These small systems are supplied by simple oil and gas fired boilers.

- o Successful experiences of utilities utilizing heat recovered from power plants for space and water heating needs.

- o Close cooperation between local governments and utilities to service infrastructure and development plan.

- o Environmental compatibility of waste-to-energy plants.

- o Job intensive factors associated with the production of heat exchangers, pipe factories meters and other related products which are the equipment parts required by district heating cooling.

- o Financing based on savings experienced over 10 years in certain cases.

- o More than 40% of all building in Denmark in both large cities and small towns are connected to district heating system. Benefits include improved air quality as a result of eliminating individual stacks and exhausts from each units.

The site visits in Denmark relate to the City of San Jose in two ways. First we gained an awareness of the reality that government, utility and the private sector can work together to make district heating work. Secondly we saw day-to-day applications in operation in homes, businesses and public buildings. The City of San Jose district heating and cooling project for the downtown superblock is closest in size to the "small" Danish systems. Conceptual plans for an expanded downtown system serving many blocks in the downtown are based on the likelihood of incorporating several small cogeneration plants each to be housed in buildings integrated into a mixed use land plan. An expanded downtown system will be similar in size to the medium sized Danish systems.

For San Jose's current and future projects the lessons learned are derived from the groups' site visit to the medium and small-sized plants, their respective piping systems heat exchangers and power sources, and the concept of using energy technology to support land use planning and development.

The following points summarize the basic findings from the tour with respect to the City of San Jose plans.

1) Less-expensive fuels and/or more efficient energy production

From the Danish experience, it would appear that California versions of district heating and/or cooling could be justified on either or both the use of less expensive fuels or more efficient technologies. Examples of less expressive fuels involve comparisons of gas vs electricity. Systems more efficient than conventional processes include the example of cogeneration.

2) Customer Billing

From the Danish tour, we learned that they designed their billing system on a number of different formulas and metering systems:

a) Measurement of hot water in volume

b) Measurement of hot water in BTU's

c) Base cost of operations and capital

d) Users cost of units consumed

e) Take or pay for some users

3) Maintenance

Our visits to multi-family housing units in Copenhagen and Odense demonstrated the similarity of operating a heating plant for many buildings as compared to operating a plant for a single building.

4) Monitoring

At numerous sites, we saw sophisticated monitoring and control equipment. Controls and programs are available to decide how much fuel to burn based on customer demand and alternatives to supplying it.

5) Waste-to-Energy

The Danes have demonstrated the viability and minimal environmental impact of mass burning waste-to-energy plants. It is apparent from this visit that technical problems for mass burning systems are not a barrier to its operation.

Next Steps

The financial viability of large scale district heating and/or cooling for San Jose depends on the demand for thermal energy and on cost competitiveness of on-site power production versus the utility's cost for electricity. Is there a scenario in which the scale of district heating as experienced in Denmark would be applied to San Jose's land use, building types, and climate? To what extent will PG&E's retail price for electricity escalate compared to efficient cogeneration units' output. Over the next few years these questions will be addressed.

Should there exist scenarios where the San Jose situation closely resembles the scale associated with district heating in Denmark, some or all of the following heat sources would likely be involved.

a) Several natural gas fueled cogeneration engine or turbine plants,

b) Single large or decentralized waste-to-energy plants, or

c) Landfill gas.

Redevelopment Agency Project Opportunities

The City is undergoing large-scale redevelopment. Many millions of dollars are being invested in new construction. Downtown projects have Redevelopment Agency involvement in one way or another - property acquisition, financing, covenants and restrictions. Therefore,

Questions before the Redevelopment Agency include:

Should the Redevelopment Agency enlist cogeneration district heating/cooling as a program to support development objectives? Are there substantial savings to developers and to the community which would justify the expense of the City offering either the program for small scale plants or the downtown city-wide plant? How can the City obtain financing and other resources from outside sources to lessen the dependency on City resources. Should the City undertake a joint partnership with PG&E to undertake this development? How can the City create investment opportunities for investors to finance energy plants in Redevelopment districts?

The City of San Jose is currently outlining options for expanding a downtown system. In this report we will:

1) outline a market plan, and suggest customers to target who will benefit from central plant as users in an expanded system;

2) suggest how to incorporate a offering energy services from central plant systems in conjunction with Redevelopment Agency projects;

3) discuss merits of constructing an underground piping infrastructure to service thermal needs of customers from energy plants;

4) identify "energy park sites" outside of the downtown which may be vulnerable to "brown-outs" and which will benefit from reliable supplies during peak demand;

5) identify third party investors who are willing to participate in these ventures and suggest provisions under which these investments will be encouraged;

6) establish parameters of the City's role as a small power producer in terms of its status as a regulated utility by the PUC including the possibility of establishing a Community Energy Authority;

7) establish conditions for wheeling power generated on-site to other locations within the City based on review of the regulatory issues within California;

8) evaluate from the City's perspective the proposal from PG&E to expand the City's downtown plan and suggest a joint venture if feasible.

Conclusions

Denmark has proven the viability of large and small scale district heating systems. San Jose has learned a great deal from the Danes about how to design, build and operate successful systems. It is now up to San Jose to determine if and how district heating and cooling can be applied beneficially for the City and its citizens.

Some of policy options for San Jose City Council to consider adopting in utilizing cogeneration district heating cooling include:

- Require all superblock redevelopment proposals be screened for inter-connection to district heating/cooling cogeneration;

- In projects considered feasible, the Redevelopment Agency will provide assistance in securing project financing including third party financing and State loans;

- Adopt a goal of encouraging economic development in San Jose by augmenting the useful output of energy used to generate electricity by connecting to cogeneration whereever feasible.

APPENDIX D -- U.S. WORKSHOPS DESCRIPTION AND AGENDAS

DESCRIPTION OF THE U.S. WORKSHOPS

In early 1985, the Energy Task Force of the Urban Consortium received support from the United States Department of Energy for the conduct of four regional workshops. These workshops were intended as a primary means to transfer results from the applied research program of the Task Force to municipal staff in other cities and counties throughout the nation. Sites initially chosen for the workshops were Baltimore, Houston, Kansas City and San Francisco. Topics were to be defined separately for each workshop to focus on energy management issues and technologies of high priority within each region. Workshops were intended to be of one and one-half day length, with a relatively open format that encouraged participant discussion and interchange.

Early discussions for the San Francisco regional workshop identified one priority topic as cogeneration and district heating/cooling. This emphasis was strengthened by work-in-progress to establish central energy systems both in San Francisco and in the neighboring city of San Jose. In continuing discussions, suggestions were made to solidify the workshop topic in the broad area of district heating and cooling and to coordinate the workshop with experience from the members of the Danish Board of District Heating.

As planning for the workshop progressed, the opportunity for an exchange of visits between U.S. and Danish practitioners centered around the workshops was discussed. This appeared as an especially valuable opportunity since current projects in San Francisco and Columbus, Ohio, are designed to use major elements in the Danish district heating approach.

In its final form, the San Francisco workshop was expanded from one regional workshop sponsored by the Energy Task Force to a series of two seminars and workshops cosponsored by the Task Force, the Danish Board of District Heating, PTI and the U.S. Conference of Mayors. As parts of this series, a one day seminar was conducted in Columbus, Ohio on October 28, 1985, with presentations primarily from the members of the DBDH. This seminar was repeated in San Francisco on October 30, with an additional workshop following the seminar.

Attendance at both the Columbus and San Francisco sessions numbered about 40 to 50 persons, each, with participants representing municipalities, utilities and private firms from a multistate area around the two cities. Papers prepared by staff from San Francisco and Columbus as a result of the Danish study visit were presented as major elements of each workshop.

Copies of the general announcement brochure and the agendas for the Columbus and San Francisco workshops follow this general description.

District Heating and Energy Systems Management

Regional Workshops for Local Governments, Utilities & Industry

Columbus, Ohio
October 28, 1985

and

San Francisco, California
October 30 — November 1, 1985

2nd Notice

Sponsored by:

City of Columbus, Ohio
City of San Francisco, California
Danish Board of District Heating
Urban Consortium Energy Task Force

In Cooperation With:

Public Technology, Inc.
United States Conference of Mayors

An Overview

The cities of San Francisco, California, and Columbus, Ohio, have joined with the Danish Board of District Heating, and the Urban Consortium Energy Task Force to offer two important energy management seminars and workshops this Fall. Each is designed to aid professional staff from local governments, utilities, and private industry in capturing the energy, economic and environmental benefits of current energy supply and conservation technology.

The seminars and workshops will bring together representatives from cities, counties and industry with expert Danish professionals and municipal energy managers from throughout the United States to:

- Examine the practical short and long range benefits of district heating and cooling systems
- Stimulate active consideration of this technology by public and private community leaders
- Review state-of-the-art techniques to implement these central energy facilities
- Expand the San Francisco seminar with in-depth workshops and two additional "tracks" for wastewater management and building energy controls
- Focus expert attention toward the solution of YOUR specific problems in energy systems management and cost control

The seminars and workshops are designed to allow you to meet and talk with our distinguished speakers and panelists, and with your colleagues from other cities and counties in the United States—to discuss problems, to exchange ideas, and to find solutions from knowledgeable professionals in both the public and private sectors.

District Heating Seminars

Columbus, Ohio (October 28), AND San Francisco, California (October 30)

Each of these one-day seminars will focus on District Heating/Cooling, combining practical expertise from members of the Danish Board of District Heating with current U.S. municipal, utility and industry experience. Plenary and concurrent sessions will cover:

- Planning, design and development
- Heat sources, products, options
- Distribution mains systems
- End-user controls and metering
- Combined heat/power production
- Peaking and stand-by concerns
- Costs, management and marketing

DHC and Energy Systems Workshops

San Francisco (October 31—November 1)

The San Francisco seminar will continue with additional workshop sessions through noon on November 1. These three concurrent workshops will provide:

- An expansion of the DHC seminars for more detailed emphasis on:
  District Heating/Cooling with working sessions to answer your specific questions
- Two additional sessions to help you manage and reduce energy costs in:
  Water/wastewater systems with attention to equipment, controls and flow management
  Building control systems with a special focus on the design, selection and use of automated control technology

COLUMBUS AGENDA

PROGRAM

0830 am	Registration and coffee.
0900	**Address of welcome** by Mayor Dana G. Rinehart.
0915	**Seminar introduction and presentation of Danish Board of District Heating** by Mogens Larsen, President of DBDH.
0930	**Presentation of Urban Consortium's Energy Task Force** by U.C.-speaker.
0945	US-Keynote Speaker.
1005	**Role of multi-consumer DH Systems in cities** by Alderman Lennart Larson, City of Odense, President of the Danish District Heating Association.
1025	**Coffee break.**
1040	**District heating in Columbus, Ohio** Speakers: Philip DeVore, Director of Division Strategic Planning. Richard Davis, Division of Strategic Planning Barry J. Shance, Vicepresident of Harry & Mogens Larsen. Timothy Barr, Deputy Director, Department of Public Utilities and Aviation.
1155	**Sum up** by Michael Long, Director of Department of Public Utilities and Aviation.
1200	**Lunch and exhibition** Luncheon speaker.
0200 pm	**Parallel sessions:**
	A. Heat sources - planning - environmental impacts.
0200-0215	**Energy from waste** Gunnar Kjaer, M.S., C. Eng., M.C.I.F., President of Vølund USA Ltd.
0215-0225	Questions.
0225-0235	**Cogeneration and environmental impacts in Columbus Downtown/Riverfront area** Kurt Damholt, B. Sc. Mech. Eng. of Harry & Mogens Larsen.
0235-0245	Questions.
0245-0255	**Savings thru condensation of fluegases in gasfired DH Boilers** K. B. Andersen, Managing Director of Dansk Fyrings Teknik.
0255-0305	Questions.
0305-0315	**Economic and financial analysis of DH Systems** Kim Donald Trøjborg, M. Sc. C. & S. E., Consulting Engineer of BHR-COWI-Energy.
0315-0325	Questions.
0325-0335	**Building Management Systems** Gert Christensen, Div. Manager of ISS Electronics, Combimeter Division.
0335-0345	Questions.
0345-0355	**District Cooling** John Hebo Nielsen, M. Sc. Ph. D., Consulting Engineer of BHR-COWI-Energy.
0355-0405	Questions.
0405-0415	**Coffee break.**
	B. Heat transportation and end user systems.
0200-0210	**Efficient heat distribution** Jens Madsen, Gen. Manager, I. C. Møller Inc.
0210-0220	Questions.
0220-0230	**Pressure transients in pipeline systems** Günther Gruschka, B. Sc. Mech. Eng., Export Manager of Brdr. Christensens Haner.
0230-0240	Questions.
0240-0250	**Plate heat exchangers for district heating** Ebbe Clausen, B. Sc. Mech. Eng., General Sales Manager of Pasilac Therm.
0250-0300	Questions.
0300-0310	**Metering of district heating** Gert Christensen, Div. Manager of ISS Electronics, Combimeter Division.
0310-0320	Questions.
0320-0330	**Air conditioning aspects in district heating** Mogens Larsen, B. Sc., Civ. Eng., Consulting Engineer, President of Harry & Mogens Larsen, Member of ASHRAE.
0330-0340	Questions.
0340-0415	**Coffee break.**
0415	**Panel discussion**
0530	**Cocktails and exhibition.**

SAN FRANCISCO AGENDA

PROGRAM

0830 am Registration and coffee.

0900 **Address of welcome**
by Mayor Diane Feinstein.

0915 **Seminar introduction and presentation of Danish Board of District Heating**
by Mogens Larsen. President of DBDH.

0930 **Presentation of Urban Consortium's Energy Task Force**
by Herbert L. Fivehouse. Chairman. Urban Consortium E.T.F.

0945 US Keynote Speaker.

1005 **Role of multi-consumer DH Systems in cities**
by Alderman Lennart Larson. City of Odense. President of the Danish District Heating Association.

1025 **Coffee break.**

1040 **District Heating in San Francisco**
Speakers:
David Rubin. Program Manager. Bureau of Energy Conservation. City and County of San Francisco.
Dr. Richard A. Wakefield. Danpower Inc.
Richard L. Mayer. Director. Marketing and Costumer Relations. San Francisco Steam Heating System. Pacific Gas and Electric Company.
Sum up.

1200 **Lunch and exhibition**
Luncheon speaker: Richard E. Eckfield. Executive Director of North American District Heating and Cooling Institute.

0200 pm **Parallel sessions:**

A. Heat sources - planning - environmental impacts.

0200-0215 **Energy from waste**
Gunnar Kjaer. M.S., C. Eng., M.C.I.F., President of Vølund USA Ltd.

0215-0225 Questions.

0225-0235 **Economic and financial analysis of DH Systems**
Kim Donald Trøjborg. M. Sc. C. & S.E., Consulting Engineer of BHR-COWI-Energy.

0235-0245 Questions.

0245-0255 **Savings thru condensation of fluegases in gasfired DH Boilers**
K. B. Andersen. Managing Director of Dansk Fyrings Teknik.

0255-0305 Questions.

0305-0315 **District Cooling**
J. Hebo Nielsen. M. Sc. Ph. D., Consulting Engineer of BHR-COWI-Energy.

0315-0325 Questions.

0325-0335 **Operation and maintenance of DH Systems**
Knud Schousboe. M. Sc. C. & S. E., Consulting Engineer and BHR-COWI-Energy.

0335-0345 Questions.

0345-0355 **Building Management Systems**
Gert Christensen. Div. Manager of ISS Electronics. Combimeter Division.

0355-0400 Questions.

0400-0415 **Coffee break.**

B. Heat transportation and end user systems.

0200-0210 **Efficient heat distribution**
Jens Madsen. Gen. Manager. I. C. Møller Inc.

0210-0220 Questions.

0220-0230 **Pressure transients in pipeline systems**
Günther Gruschka. B. Sc. Mech. Eng., Export Manager of Brdr. Christensens Haner.

0230-0240 Questions.

0240-0250 **Plate heat exchangers for district heating**
Ebbe Clausen. B. Sc. Mech. Eng., General Sales Manager of Pasilac Therm.

0250-0300 Questions.

0300-0310 **Metering of district heating**
Gert Christensen. Div. Manager of ISS Electronics. Combimeter Division.

0310-0320 Questions.

0320-0330 **Air conditioning aspects in district heating**
Mogens Larsen. B. Sc., Civ. Eng., Consulting Engineer. President of Harry & Mogens Larsen. Member of ASHRAE.

0330-0340 Questions.

0340-0415 **Coffee break.**

0415 **Panel discussion**
Introduction and briefing on work shop by Rich Zelinski, Public Technology Inc.

0530 **Cocktails and exhibition.**

Report and Information Sources

Additional copies of this report, "District Heating in Denmark: Report from a Technology Exchange", and further information about the programs and products of the Energy Task Force of the Urban Consortium are available from:

Public Technology, Inc.
1301 Pennsylvania Avenue, NW
Washington, DC 20004

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