District Energy as a Response to Climate Change: The Experience in Europe and the Potential in America

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ABSTRACT

Climate change has the potential to be the most serious problem that our civilization faces, and the greenhouse gases responsible for the danger are due to human activities. District energy is a concept that results from combining district heating and cooling with the generation of electricity. District energy can play an important role in the climate-change strategies under consideration by policy makers by offering a technology to significantly reduce CO_2 emissions. The well-documented economic and environmental benefits of a district energy system utilizing various combinations of simultaneous generation of heat, chilled water, and electricity are discussed briefly in this paper. An overview of the technological innovations, applications, and future trends in district energy systems with cogeneration is provided, particularly as they relate to the renovation and replacement of existing systems. At the present time, district energy is underutilized and serves only 1.3% of the U.S. energy needs. This paper presents a simple model for implementing increased utilization of district energy in the U.S. based on the experience in comparable European Union (EU) countries. Attainment of the Kyoto Climate Change Protocol, the 7% reduction of CO_2 emissions from 1990 levels by the year 2012, is discussed in the context of the potential contribution of increased utilization of district energy. By reaching par with comparable EU countries, the U.S. could achieve a 3% reduction in total national CO_2 emissions. With 100% implementation of district energy serving the heating market sector, the U.S. could achieve an 8.5% reduction in CO_2 emissions. Further significant reduction in CO_2 is possible with district energy concepts by redirecting national policy on the use of internal combustion engines through integration of the transportation energy sector with industrial, building, and power plant sectors; a major electrification of our transportation infrastructure would likely result. Increased implementation of district energy thereby addresses the risks posed by current global climate change theories and is a necessary condition for the U.S. to achieve CO_2 emission reductions.

INTRODUCTION

District heating and cooling, also known as district energy, commonly used in Europe, is a technology that is underutilized in the U.S. In light of current global pressures, increased implementation of district energy in the U.S. may now be possible. Climate change has the potential to be the most serious problem that our civilization faces; greenhouse gases responsible for the danger are caused in large part by human activities. District energy can play an important role in the climate change strategies under consideration by policy makers. The economic and environmental benefits of a district energy system utilizing various combinations of simultaneous generation of heat, chilled water, and electricity have been well documented and will be discussed briefly. Increased implementation of district energy will offer unsurpassed reductions in emissions through improved operating efficiencies, utilization of clean fuels, and access to renewable and non-fossil-based energy sources. Attainment of the Kyoto Climate Change Protocol, the 7% reduction of U.S. CO_2 emissions from 1990 levels by the year 2012, is discussed in the context of the potential contribution of increased utilization of district energy by reaching par with comparable European Union (EU) countries.

BACKGROUND: SYSTEM CONCEPTS

District Heating and Cooling (District Energy)

A district heating and cooling system (DHC) provides thermal energy in the form of steam, hot water, or chilled water from a central plant and distributes the energy through pipes

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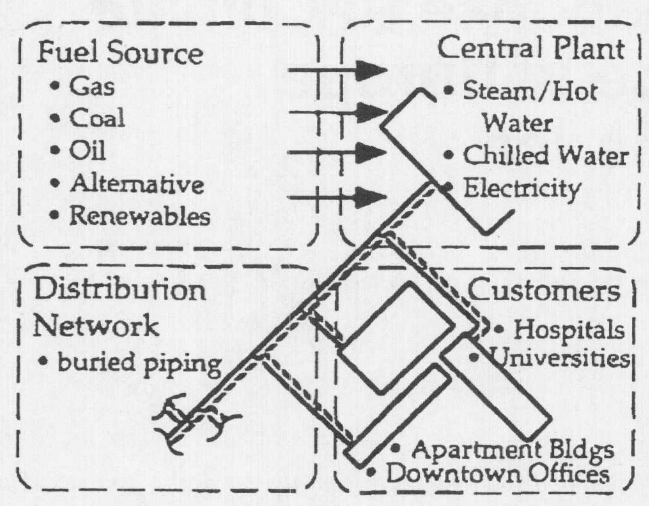

Figure 1 *Typical district energy system.*

to two or more buildings. The most efficient and cost-effective DHC system available today will include electrical generation typically through a cogeneration process. With the growing trend of DHC plants to integrate all three energy utilities (heating, cooling, and the generation of electricity), DHC systems are now more commonly referred to as district energy systems.

All district energy systems have four basic components: a fuel source, the central production plant, a distribution network, and its connected customers (Figure 1). Typically, thermal energy is used for space heating, space cooling, or process needs, and when combined with the production of electricity in the central plant, it is also considered to be a cogeneration facility. Combined heating, cooling, and power generation in a single facility can offer attractive investment returns with lower capital costs than other alternatives (Skaer 1995; DOE 1993).

Historical Development of District Energy

The concepts of district energy have been applied for many years. The Romans of Pompeii used geothermally heated water running through open trenches to serve community baths. Birdsill Holly in 1877 established the first commercial district heating system in the U.S. in Lockport, New York, and served 14 customers. District energy systems have been used in Europe since the 1890s and, because of scarce gas and electricity supplies, have always done well. In most large U.S. cities, district energy has prospered during the first half of this century where district heating was economically combined with electrical generating plants. The use of district energy declined in the U.S. after 1945 with the development of new electrical generation plants outside urban areas precluding the economic application of district heating. Lower cost electricity, gas, and oil forced the closing of many district energy companies. The oil crisis in the 1970s brought a resurgence in the application of district energy, which can take advantage of alternative energy resources (Bond 1993). After the first Arab oil embargo, the U.S. reacted quite differently than the EU countries and Pacific rim countries to the threat to energy security. The U.S. emphasized defense spending and other measures to secure stability in the Middle East, increased exploitation of internal fossil fuels, and sought out alternative suppliers for fossil fuels. The U.S. strategy has been successful in securing stable, relatively low energy prices for the U.S., but it leaves questions of long-term supply and environmental impact of current use largely unaddressed. Europe and the Pacific rim countries have participated to a lesser extent than the U.S. in political and military stabilization efforts in fossil fuel supply regions, but they have also emphasized domestic and industrial energy efficiency and district energy to a greater extent than the U.S.

Status of District Energy in the U.S.

The Department of Energy (DOE) in a 1993 census estimates there are 6,000 operating district energy systems in the U.S., representing a combined 800 billion Btu/h of thermal production capacity and providing over 1.1 quadrillion Btu of energy annually delivered through 20,000 miles (32,000 km) of distribution piping. Presently, district energy in the U.S. serves 12 billion square feet of spaces that include office, education, health care, military, industrial, and residential spaces. College campuses, hospitals, and military installation account for 75% of all district systems. Steam is produced and distributed in 44% of the systems, chilled water is produced in 33%, and cogenerated electricity in 10%. The average system serves between 11 and 50 buildings, with a combined area of 2.6 million square feet. Median ages for system components are 31 years for distribution systems, 23 years for boilers, and 15 years for chillers. In the U.S., the total commercial and residential heating market is about 10 quads, and with the 1.1 quads provided by district heating systems, district energy has an 11% penetration into this sector. For cooling, the total market in the U.S. is about 1.3 quads, of which only about 0.1 quad is provided by district cooling (DOE 1993).

World Energy Consumption and District Energy's Share

The issue today fueling the energy consumption debates is not depletion of world energy resources but the concern over the atmosphere's holding capacity and ability to absorb the various effluents from the combustion of fossil fuels, chlorofluorocarbon (CFCs) releases, and worldwide agricultural practices. The limitations in environmental holding capacities need to be understood; the science of this very complex matter is in its infancy, but our knowledge is increasing rapidly. Energy that drives our world economies is derived from a variety of sources: fossil fuels (coal, gas, and oil), biomass, wind, solar, hydro, nuclear, and, to a limited extent, geothermal and tidal power. Energy that is used to improve the quality of life can be categorized by major energy use sectors: industrial, transportation, residential, commercial, and agricultural. Today, the world consumes the

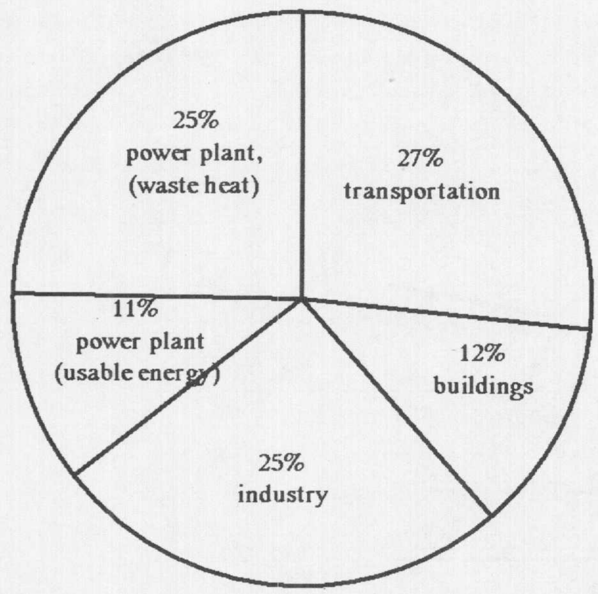

Figure 2 *U.S. energy use categories.*

equivalent of 200 million barrels of oil each day (1.2×10^{15} Btu/day) (Davis 1990). The U.S. and Canada have the highest per capita consumption rates. The U.S., with only 5% percent of the world's population, is responsible for 25% of world energy consumption and uses this energy as detailed in Figure 2. District energy today consumes about 1.3% of all energy used in the U.S. each year. District energy systems are an important part of the U.S. energy use and delivery infrastructure; however, these numbers suggest that at the present time, district energy is underutilized in the U.S. and could feasibly represent a much larger percentage of total consumption (DOE 1993).

The Advantages of District Energy

The International Energy Agency (IEA) and the International District Energy Association (IDEA) have produced reports and studies on district systems that offer useful insight to the applications and benefits of this technology. Generally a district energy system, if properly implemented, can save money, energy, and reduce pollution. IDEA has developed a list of eight reasons why district energy is a practical technology for heating, cooling, and energy generation applications (Bond 1993):

1. offers lower capital costs,
2. realizes lower energy costs,
3. obtains lower operating and maintenance costs,
4. supports stable competitive energy rates,
5. allows for more revenue-generating space,
6. ensures reliable heating and cooling service,
7. provides lower costs through system expansion, and
8. ensures a cleaner environment.

The eight examples sited above are achieved through combined benefits of

- enhanced energy utilization,
- improved operations management,
- improved electric load management,
- above average part-load efficiency,
- heating and cooling integration with power generation,
- limited number of emission sources,
- ease of technical upgrades, and
- higher design efficiencies.

Why Laissez-Faire Market Forces Have Not Led to Greater Use of District Energy

Energy costs are lower in the U.S. than in comparable EU and Asian Pacific Rim countries. Hence, while district energy systems can still deliver energy to the end user more economically than distributed systems, the price differential is only about 6% in the U.S., as compared to many EU countries, where district energy can deliver energy at a much greater price differential. A district energy system would typically add about one-third to the capital cost of doing business in a given area, as compared to the use of conventional technologies. Although the distribution portion of a district system is a very long-lasting investment, it is an investment typically amortized over a relatively short period. In addition, even though cogeneration and other waste heat-based district systems can offer customers rates based on very low fuel costs, the debt component of new projects often drives the total unit cost of energy above conventional alternatives for multi-year periods after the inception of a given district energy project. The result is that unit energy costs rise over the period of initial implementation of a district energy scheme (Figure 3). In an economic culture as devoted to short-term profitability as is the U.S., this initial rise in price, vis-a-vis conventionally delivered energy, can make a prospective district energy project difficult to sell to potential customers (Spurr 1996).

Trend-Setting Concepts in District Energy

The overall competitiveness of district energy has improved as a result of recent innovations; now district energy can be developed at a lower unit cost with higher operating efficiencies and with greater flexibility than previously possible (Mornhed and Casten 1995). Participants within the district energy industry have made significant technology breakthroughs. The International Energy Agency (IEA), established in 1974 to strengthen cooperation among member countries, along with others, supports cooperative R&D activities in district energy.

Cogeneration with Combined Cycle Gas Turbines. Technological innovations in the use of gas turbines have been critical to implementing cogeneration. Today, a 150 megawatt gas turbine can be installed for a cost as low as $400/kW. Due to very favorable economics, low first-cost and short construc-

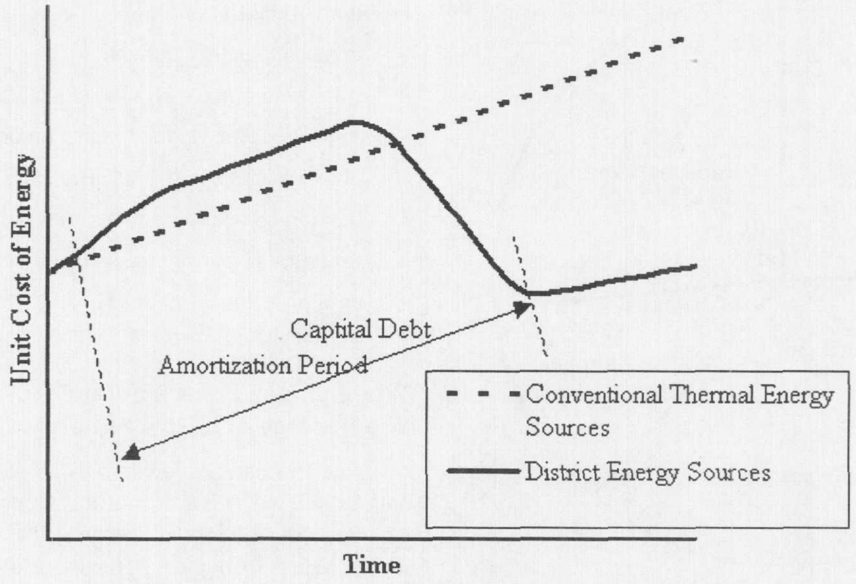

Figure 3 *Total energy unit costs for district energy projects vs. conventional energy baseline costs.*

tion time, it is evident that until a significant change in the price of natural gas vs. other fuels occurs, the natural gas fired combined cycle will be the main type of plant installed for electricity and cogeneration. A variety of combined cycles are in use today:

- combined cycle gas turbine (CCGT),
- steam injected gas turbine (STIG),
- pressurized fluidized bed cycle (PFBC), and
- integrated gasification combined cycle (IGCC).

The main components of a CCGT are shown in Figure 4. CCGT will see continuing development, mainly in the increase in turbine entry temperature (TET), thus adding 6% operating efficiency by 2010. Typical CCGT cogeneration energy conversion efficiencies can be as high as 85% - 90%, when all the waste heat associated with electrical power production is utilized for heating purposes or cooling by applying absorption technologies. This compares favorably with typical electric power generation efficiencies of 30% - 35% (MacViro 1992; Moore 1993).

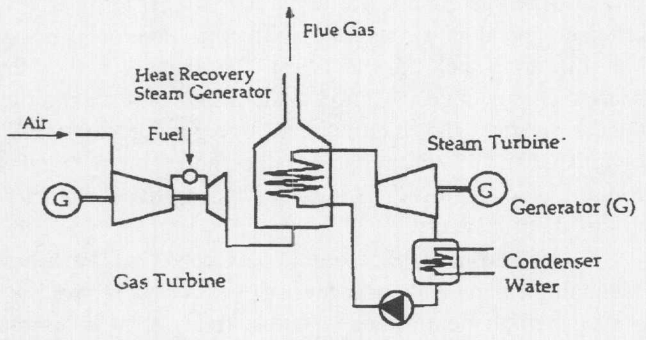

Figure 4 *Combined cycle gas turbine.*

Clean Coal Technologies. Large U.S. coal reserves provide the incentive for the ongoing development of clean coal combustion, using the inherent advantage of a combined cycle to attain high efficiencies. We should expect to see progress with coal gasification and various forms of PFBC and IGCC, which will require that high gas temperatures be attained in a particulate free combustion process known as the "hot gas clean-up" concept. However, the virtual absence of sulfur in the natural gas supply further provides a major cost advantage over clean coal technologies (Moore 1993).

Heat Pumps. District energy does not just include heat utilization at central heating plants. District energy systems can also be sited centrally at thermal sources and distribute that energy to points of demand. Heat pumps can be used to extract heat from waste water such as at municipal and industrial waste treatment plants and any other large thermal resources. The heat pumps utilize both the low-grade heat reservoir for heating applications and, when operating in reverse, use the same source as a heat rejection sink during a cooling cycle.

Fuel Cells. Phosphoric acid fuel cells (PAFC) are beginning to achieve commercial viability and offer a certain degree of reliability, efficiency, and lower emissions compared with other fossil-fuel-based electric generation. Today, approximately 200 PAFC installations operating at 400°F provide 50 megawatts of total energy in various facilities throughout 15 countries worldwide; approximately half of these include thermal recovery concepts for heating applications. District energy systems are expected to utilize advanced features of fuel cell technology in the future (Hirschenhofer and McClelland 1995).

Geothermal. Growth in direct-use geothermal applications has been significant, at an increase of 500% between 1975 and 1990, expanding to 18×10^{12} Btu/yr in geothermal energy. It is expected that this rate of growth will accelerate in the future. Geothermal power offers an attractive alternative energy source for district energy applications in that it can displace the use of conventional greenhouse emitting fuels. Unlike solar and wind alternatives, geothermal power is not limited by cyclical output and availability, so it can provide an efficient base load operation (Rafferty 1995).

Chiller Technology. Future developments in the various refrigeration machines will be driven by cost, operating efficiency, acceptable refrigerants, containment methods, noise control, and overall product quality. Various drive configurations are possible, including constant- and variable-speed electric motors, gas-fired reciprocating engines, and steam turbines. Other available cooling technologies practical for a district system include multiple-stage gas direct-fired absorption and multiple-stage steam absorption. The most efficient chillers today are the new turbo-charged centrifugal machines. Technological advances continue to improve the operating efficiencies of centrifugals. Smaller centrifugal machines can now obtain efficiencies of 0.51 to 0.55 kW/ton. Unless a completely new method of conventional cooling is discovered, the refrigeration industry does not anticipate long-term technological improvements that will exceed operating efficiencies above 10% of those available today. Current refrigeration machines have been optimized and are approaching their theoretical limits of operating efficiencies.

Thermal Energy Storage (TES). A significant interest has developed in large-scale stratified chilled water storage with many successful projects recently coming on-line. TES offers electrical demand and rate savings through chilled water production during off-peak hours that can then be stored for later dispatch during peak cooling demand periods that are coincident with peak power consumption and on-peak electric rates. TES allows the more efficient base-loading of installed chiller capacity and operation at optimum efficiency (Mornhed and Casten 1995; MacViro 1992).

Deep Water Source Cooling. Utilizing large, natural, cold water bodies as a renewable thermal energy source and heat sink for process and comfort space cooling is a promising technology called deep water source cooling (DWSC). Water at a constant 40°F - 50°F or less is withdrawn from deep areas within lakes, oceans, aquifers, and rivers and is pumped through the primary side of a heat exchanger. On the secondary side, clean chilled water is produced with one-tenth the average energy required by conventional chiller-based systems. Coincident with significant energy and operating cost savings, DWSC offers reductions in airborne pollutants and the release of refrigerants. Functional DWSC systems are in Halifax, Nova Scotia, and Stockholm, Sweden. The city of Toronto is studying this application using Lake Ontario, and Cornell University in Ithaca, New York, is proceeding with the construction of a 20,000 ton capacity DWSC facility (Burford et al. 1995).

ATTAINMENT OF KYOTO PROTOCOL

As a result of summits in Rio de Janeiro and Berlin, with U.S. agreement, the Intergovernmental Panel on Climate Change (IPCC), through the Framework Convention on Climate Change, initially called for stabilization of CO_2 emissions to 1990 levels by the year 2000. In 1995, U.S. emissions were estimated to be about 5% higher than in 1990 and were showing no sign of leveling off. The IPCC has since demonstrated that countries need to reduce global emissions to well below 1990 levels if the concentration of CO_2 in the atmosphere is to remain stable. As a result, the IPCC called for a 20% reduction below 1990 levels, a goal known as the "Toronto Target." The U.S. never supported the Toronto Target because of possible impacts on the economy (BCS 1996). Most recently, the Kyoto Protocol, negotiated in 1997 by representatives of 160 countries including the U.S., calls for the legally binding 7% reduction of CO_2 emissions from 1990 levels by the year 2012. The Kyoto accord will require ratification by the U.S. Senate and still faces significant resistance.

Global Climate Change

The natural baseline for CO_2 during pre-industrial periods was found at 280 parts per million (ppm). Today, atmospheric CO_2 levels are increasing and have reached over 360 ppm; this represents a 25% increase in atmospheric CO_2 concentrations as a result of human activities (Holdren 1990). Greenhouse gases being added to the atmosphere may remain there for multiple decades and are predicted to increase average global surface temperatures by several degrees Celsius. This is a change larger than what has occurred over the past 15,000 years (NOAA 1996). As a fuel, coal releases nearly twice as much CO_2 per Btu as natural gas. In the U.S., gas-fired generators account for 15% of electrical generation and produce just 9% of electricity-related carbon dioxide emissions. However, coal currently accounts for 52% of total U.S. electric generation and, as a result, produces 87% of electricity-related carbon emissions (EIA 1996).

U.S. Energy Use Forecasts

Environmentalists may desire a U.S. energy use profile in the year 2015 that supports a sustainable world view with significant improvements in efficiency and demand stabilization after the year 2000. However, the energy outlook from the Energy Information Administration, a division of the DOE, forecasts (EIA 1996):

- sharply lower use of nuclear power;
- greater use of natural gas and coal;
- slower application of renewable technologies until 2010 when application accelerates somewhat;

- the continued rise of CO_2 emissions, likely to increase 40% from 1990 by 2015, and 45% by 2020; and
- flat or declining electricity prices.

This outlook is based on a projected 32% drop in nuclear generated electricity due to retirement of 40% of current nuclear capacity. During this period, many reactors will reach the end of their expected 40-year operating lives. Prices for natural gas and coal are expected to decline because resource estimates will increase and extraction technologies will improve. Lower prices for conventional coal and gas will slow the market for renewable generating technologies and, despite efficiency improvements, will lead to greater use of fossil fuels (EIA 1996). District energy in the U.S. should be expected, on average, to use fuels that are consistent with the national trends.

THE EXPERIENCE IN EUROPE

The Europeans, unlike the U.S., have extensive distribution systems functioning successfully. The Europeans are less tolerant than the U.S. about the wasting of two-thirds of the thermal energy in conventional plants and have created incentives for heat recovery. Waste heat capture can afford considerable savings and the Europeans have been able to realize these savings for a number of years now. Many European urban areas with district systems exceed 75% overall operating efficiencies, which is considerably better than the 40% efficiency typical of most urban zones in the U.S. Helsinki, Finland, for example, achieves a 78% overall operating efficiency by extensive use of district energy. Table 1 highlights a few of the heating market penetration rates, average distribution size, use of cogeneration, and alternative fuel applications in several EU countries. In Germany, the attitude is to serve 100% of a location with district energy. Table 2 further outlines specifics on selected systems in the EU. Certainly there are many valuable lessons to be gained from the EU experience with district energy.

TABLE 1
The Experience in Europe

	Heating Market Penetration	Average Distribution Size, Miles (km)	Cogen.	Alternative Fuels
Scandanavia	35%	33 (53)	39%	25%
Denmark	50%	39 (63)	62%	25%
Iceland	85%	50 (80)	10%	100%
Germany	12%	38 (61)	NA	NA
USA	11%	3 (5)	10%	5%

THE POTENTIAL IN AMERICA

With penetration rates still very low in the U.S., there are significant opportunities for increased utilization of district energy. However, the district energy that has been developed in the U.S. offers valuable lessons for any new development. Table 3 outlines three separate U.S. systems that serve as good examples for those interested in learning about district energy. To simplify applications, listed below are three archetypal categories to which most potential district systems would be applicable:

1. small institutional single entity, such as a college or university;
2. private enterprise investor-owned system;
3. large system with local government brokering the development.

IMPLEMENTATION MODEL (INCREASED U.S. UTILIZATION OF DISTRICT ENERGY)

Basis of Model

Increased utilization of district energy in the U.S. is a practical tool to assist with meeting the Kyoto Protocol. Just how close the U.S. can come to meeting the Kyoto Protocol for CO_2 reduction in part depends on how much increased utilization is feasible. One way to analyze this potential consists of

TABLE 2
Performance Summaries of Typical District Systems in Europe

Location	Project Components and Prime Movers	Power Output	Heat Output	Heat Ratios	Overall Operating Efficiency
Sheffield Heat & Power Ltd. Sheffield, Great Britain	One waste-to-energy plant with two boilers and one back-pressure turbine 28.8 km distribution pipeline	31 MW	43 MW	0.72	> 60%
Goteborg Energi AB Goteborg, Sweden	Wide variety of heat production units including heat pump extraction at sewage plants and heat recovery from industry	< 200 MW	800 MW	< 0.25	> 70%
BEWAG District Heating Berlin, Germany	Fifteen electric cogeneration plants with an extensive hot water distribution network throughout its service territory	2,833 MW	6,056 MW	0.47	> 70%

TABLE 3
Performance Summaries of Typical District Systems in the USA

Location	Project Components and Prime Movers	Power Output	Heat Output	Heat Ratios	Overall Operating Efficiency
University of Rochester Rochester, NY	Three coal fired and two oil fired steam boilers, four steam-turbine driven chillers totaling 53 MW cooling	0.0 MW	85 MW	N/A	58%
Grays Ferry Cogeneration Philadelphia, PA	One dual-fuel combined-cycle gas turbine heat recovery steam generator (HRSG), one steam turbine	150 MW	352 MW	0.43	> 70%
Con Edison New York, NY	Seven electric plants fired with gas and oil with multiple back-pressure steam turbines located throughout distribution territory	3,534 MW	3,307 MW	1.07	> 60%

building a simple economic model based on demographic data and comparisons with the U.S. competitors, particularly the EU countries.

The potential for district energy penetration (DEP) in the U.S. as a percent of total national energy use could equal district energy penetration typical in those EU countries that encourage development of district systems. This would be a great Phase-I target for the U.S. and can be justified through comparison of climates, urban densities, and levelized per capita energy consumption.

At first glance, there would seem to be significant climatic differences between Scandinavian population centers and the band between 35° and 45° north latitude, where most winter heating takes place in the U.S. Scandinavian urban centers tend to fall mostly in maritime climatic zones, and U.S. heat belt cities tend to have continental or quasi-continental climates. Examination of climatological data, however, demonstrates reasonable similarity in average winter conditions. From Figure 5 (Critchfield 1927), it can be seen that on the whole, coldest month temperatures tend to be somewhat more severe (in relation to overall heating degree-days) in typical heating belt cities in the U.S. than they are in typical Western and Central European cities. Overall, the magnitude of the heating season is fairly comparable. U.S. cities would appear to experience considerably more severe cooling season weather than their European compeers.

Urban concentrations in the U.S. are basically equivalent to those in EU countries (Figure 6) (Bureau of the Census). The authors assume that EU countries are much further ahead in implementing district energy (DE) and that if the U.S. could achieve the EU level, it would be a significant accomplishment for the U.S. Certainly, the EU countries are expected to continue to increase their DE penetration percentages over time. The U.S. was one of 17 countries in the world that in 1995 had gross national products in excess of $15,000 per person per year ($U.S). These 17 countries fall into two groups: continental

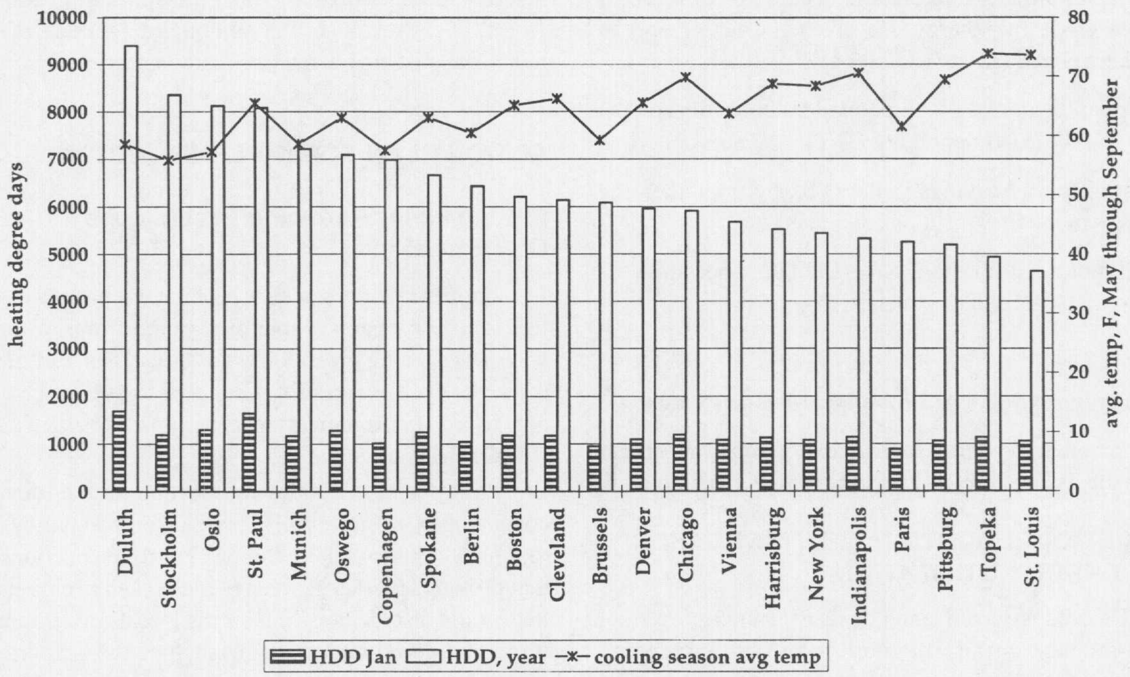

Figure 5 Typical heating degree-days.

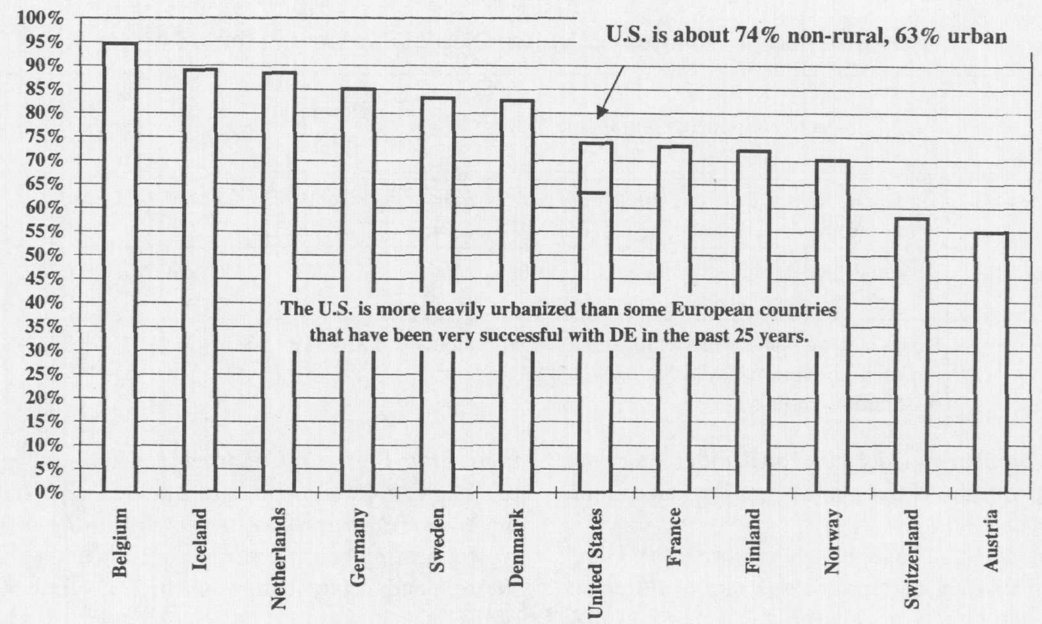

Figure 6 *Urban population as a percentage of total population.*

size nation states with substantial internal fossil fuel resources (U.S., Canada, Australia) and everybody else (Japan, Singapore, and EU countries). In 1995, the U.S. used 63% more total energy on a kg/$ per capita gross national product (GNP) basis than the average country in the peer group list (Table 4). Total energy serves transportation, power plants, industry, and buildings. Change in the transportation energy use sector is not expected as a part of this analysis and it will not affect the results unless integrated with district energy applications. To factor out the argument that each country's energy use is not directly comparable because of differences in per capita GNP, the energy use of each country can be viewed on a levelized (*L*) kg/$ GNP basis:

Lkg = (per capita annual kg oil equivalent consumption) / ($US per capita GNP)

Thus, potential energy savings in the U.S., by implementing district energy in the U.S., can be calculated as:

new DEP potential for the U.S. = (EU DE penetration - U.S. DE penetration),

and so

U.S. energy savings = DEP × total U.S. energy use

With the potential energy savings expressed as a percent of total use, the associated CO_2 savings are easily calculated.

POTENTIAL CO_2 REDUCTION WITH INCREASED DISTRICT ENERGY UTILIZATION

If the U.S. constructed enough district energy system distribution mileage to raise the portion of building energy input that is filled by district systems to about 35%, the simplified model estimates that U.S. 1995 base CO_2 emissions would decrease by about 3%, with other variables remaining the same. This is assuming that virtually all new district energy projects involve either cogeneration of electricity or use of waste heat from existing thermal plants. Were the U.S. to achieve near complete utilization of opportunities for district energy to serve the heating market, the reduction in CO_2 would be closer to 8.5%. Further significant reduction in CO_2 is possible with district energy concepts by redirecting national policy on the use of internal combustion engines through integration of the transportation energy sector with industrial, building, and power plant sectors (Figure 2), a major electrification of our transportation infrastructure would likely result. In the potential magnitude of emissions reduction, district energy ranks among the greatest opportunities open to the U.S.

ACTION PLAN FOR IMPLEMENTATION

Strategies for Reducing Greenhouse Gas Emissions

Improvements in energy efficiency, changes in the type of fuel, and use of renewable energy are some of the possible ways of reducing greenhouse gas emissions. Further, enhancing sinks or reservoirs for greenhouse gases, such as improving forest management and land-use practices, can help (UNCCB 1996).

Policy makers today are promoting a dual strategy consisting of a "no-regrets" and "insurance policy" response to global climate change threats. No-regrets actions are those that provide leverage against perceived environmental threats that would also be beneficial if the threats never materialized. Important no-regrets strategies include the encouragement of energy conservation programs that support the efficient use of energy. Insurance policy actions involve making reasonable investments into energy research and development today, so as

TABLE 4
Levelized Oil Equivalent Consumption*

Country	1995, Millions Population	% Urban Population	Per Cap. Ann. Oil Equi. Cons., kg	Per Cap. GNP, $US 1995	kg/$pc GNP
Japan	125.46	77%	3,586	$36,775	0.10
Switzerland	7.07	68%	3,694	$37,390	0.10
Austria	8.11	59%	3,266	$24,815	0.13
Denmark	5.21	85%	3,729	$27,119	0.14
Italy	57.29	67%	2,697	$18,500	0.15
France	58.36	73%	4,034	$26,175	0.15
Norway	4.35	76%	4,925	$26,430	0.19
Germany	81.84	86%	4,358	$23,095	0.19
Singapore	2.99	100%	4,399	$22,575	0.19
Netherlands	15.49	89%	4,560	$22,250	0.20
UK	58.21	92%	3,743	$18,075	0.21
Belgium	10.11	96%	5,100	$23,040	0.22
Sweden	8.95	84%	5,395	$22,515	0.24
Finland	5.12	60%	5,560	$20,275	0.27
Australia	18.19	85%	5,263	$18,320	0.29
United States	262.77	76%	7,622	$26,360	0.29
Canada	29.66	78%	7,912	$19,240	0.41

* 0.18 = average, all countries > $15 K per cap GNP, except Australia, U.S., Canada; 0.29 U.S.; 63% U.S. overage; 132% Canada overage; 62% Australia overage

to have a contingency plan for tomorrow if no-regret efforts are not adequate. Alternative energy sources such as solar, wind, ocean thermal, and geothermal, that today are not economical, can only be developed through a committed R&D effort. Such R&D can be effectively funded through a carbon tax that could come in the form of gasoline, coal, natural gas, and oil consumption taxes. The Clinton administration is working on reasonable proposals for the funding of our insurance plan.

Natural gas is at best a short-term solution; it should not be considered a long-term sustainable energy source but rather as an interim fuel of convenience with the lowest environmental consequences until we develop more appropriate technology, such as inherently safe nuclear power or other non-fossil-fuel based resources. Nuclear energy, which has no climatological impact, has great promise. But until a new generation of reactors can be developed, radioactive wastes can be managed safely, and concerns for nuclear weapons proliferation are controlled, this technology will not see increased application. Fusion has the potential to reduce the safety, waste, and proliferation hazards of fission, but there remain many uncertainties as to when, how, and at what cost it can be made available (Holdren 1990).

Strategies for Closing the Energy Efficiency Gap

The three most promising strategies for addressing the U.S. energy efficiency gap with the comparably prosperous EU and Pacific Rim nations are to

- increase process efficiency in individual industries,
- improve efficiency of residential appliances,
- increase use of district energy systems.

All three of these strategies are of roughly equivalent value in increasing energy efficiency of the U.S. economy and decreasing emission of greenhouse gases. These measures are a way of substituting capital investment for energy inputs to a given economy. The first two opportunities are being addressed within the U.S. economy to a much greater extent than is the large-scale adoption of district energy. Process efficiency in industry can result from individual investment decisions by business owners and corporations. Increases in U.S. domestic appliance efficiency happened largely through federal government mandate.

The U.S. government can support district energy development by considering the supply-side options and providing aid for comprehensive regional heat plans. This can be achieved by promoting Green Cities (a new EPA initiative) and encouraging concerned citizen involvement. The demand-side management (DSM) and EPA's Greenlights programs of the 1980s and 1990s were successful energy conservation programs that can provide a reasonable framework for a new governmental support initiative of district energy. There is an opportunity for ASHRAE to take a leadership role in promoting the use of district energy and its benefits.

CONCLUSIONS

District energy systems have made relatively little impact on the efficiency of the U.S. economy because the key tool necessary for implementation, regional thermal system analysis and planning, are largely nonexistent in the United States. The 1993 German Energy Program and the 1979 Danish Heat Supply Act are examples of central government policies designed to foster the regional planning for domestic and commercial heating and cooling supply that is necessary for the success of new district energy schemes.

Even though district energy systems are a good idea, they will not be implemented sufficiently or quickly through existing market forces. Observation of current trends indicate some of the reasons.

1. In the United States, the concept of district energy is relatively unfamiliar to developers, to community and regional planners, to state and local government officials, to engineers and architects, and to the voting public in general.

2. Constructing district energy systems can be a no-regrets way of reducing CO_2 emissions, that is, a way that actually saves money. But no-regrets only applies if one is looking at the necessary investment over a long period of time. Within a shorter time frame, district energy opportunities typically (though not always) offer a lower rate of return on investment than what potential private sector financiers are willing to accept.

Regarding attainment of the 7% reduction target agreed to in Kyoto, by reaching par with comparable EU countries, the U.S. could achieve a 3% reduction in total national CO_2 emissions. With 100% implementation of district energy serving the heating market sector, the U.S. could achieve an 8.5% reduction in CO_2 emissions. Further significant reduction in CO_2 is possible with district energy concepts by redirecting national policy on the use of internal combustion engines through integration of the transportation energy sector with industrial, building, and power plant sectors; a major electrification of our transportation infrastructure would likely result. Increased implementation of district energy thereby addresses the risks posed by current global climate change theories and is a necessary condition for the U.S. to achieve CO_2 emission reductions.

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