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Focus on the Trenton DHC/Cogeneration System

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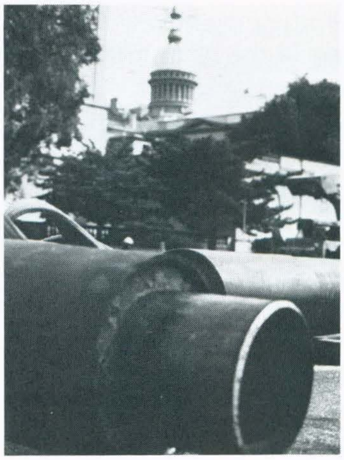
Cogeneration and DHC in Trenton

by Tom Casten, President and Kevin Brown, Marketing Manager, Cogeneration Development Corporation

The development of a district heating/cogeneration system in Trenton, NJ shows that the development of new systems can be economically feasible. It also shows the institutional problems that need to be faced with any system, and the problems that can come with using new technology. All the problems were dealt with and TDEC is thriving and growing.

The Trenton District Energy Company's (TDEC) cogenerated district heating system went into service in December, 1983. This was the culmination of many years of study and design that started as a concept for an integrated community energy system for the City of Trenton to revitalize its central business district.



Piping system for Trenton being installed, with the New Jersey Capitol Dome in the background.

The City of Trenton

Trenton is the capital of New Jersey with a current population of 92,000. Although the city was once a prosperous industrial center with major steel and porcelain industries, it has suffered a loss of tax base and the erosion of the central city characteristic of many older urban areas in the Northeast. A major surviving "industry" is the state government.

Although hot water district heating is well known in Europe, the Trenton project is one of the first hot water systems in the U.S. There were no institutional and financial arrangements in place and little legal guidance for a project of this genre. The development of the system was an educational process for all concerned-potential users, the New Jersey state legislature, Public Utility Commission, the local investor-owned utility, state environmental regulators, thermal users and the private developer as well.

From May of 1980, when the Trenton City Council appointed Cogeneration Development Company as the project's sole developer, until December 1982 when the initial financing was completed, all of the institutional arrangements were hammered out. The Public Service Electric and Gas Company (PSE&G) had little prior history of purchasing privately generated electricity and was understandably reluctant to establish precedents without full understanding of the consequences.

Public Utilities Board Convinced; Governor Enlists Support

Convinced that the economics of fuel savings through district heating made sense, the state Board of Public Utilities eventually intervened as an unbiased third party to reassure PSE&G that its market was not threatened by the Trenton system. The Board helped arrange an agreement for the purchase of the cogenerated electricity.

The Governor of New Jersey enlisted the support of the state legislature to permit a long-term contract for district heating in state-owned buildings. Twenty year contracts to heat and cool the state building complex in Trenton, the City and Mercer County and the contract for electricity sales to PSE&G assured a core of long term customers for the system and lessened the financial risk for potential private investors. Other thermal users were added after this essential "core" group had entered into contracts. The City of Trenton worked with the district heating company in marketing the system, helped secure a contract with the second largest user, the Mercer Medical Center and continues to make potential real estate developers aware of the availability and attractiveness of thermal supply from TDEC.

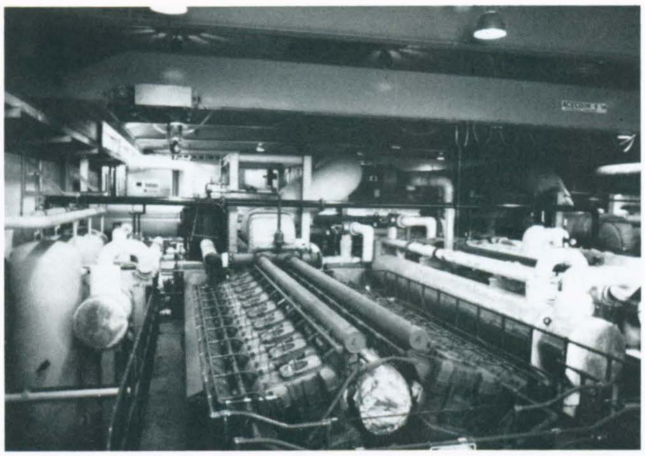
The DHC/Cogeneration System

The TDEC project consists of a cogenerated district heating system located at an urban renewal site in downtown Trenton. In addition to producing thermal energy, the plant is inter-connected with and selling electricity to Public Service Electric & Gas. Two diesel engine generator sets coupled with two supplementary fired waste heat boilers are used to cogenerate electricity and the thermal energy required for the hot water district heating system.

High temperature hot water is distributed through insulated underground pipes to the Company's customers. Upon delivery the high temperature hot water is converted by heat exchangers to a variety of thermal energy forms depending on the equipment and requirements of each building such as: steam or hot water to heat buildings, provide for domestic heating and cooling needs, operate absorption air conditioning systems and, at Mercer Medical Center, to sterilize hospital and laboratory equipment and be utilized in the hospital laundry. The buildings and corresponding estimated thermal energy demands currently contracted for are listed in the adjoining box.

The principal components of the plant include two Cooper Bessemer diesel engines (8330 hp, 400 rpm) connected to two General Electric electric generators each having a rated output of 6,000 kw. These engines are capable of burning No. 2 fuel oil or natural gas. Each diesel engine will be connected to an International Boiler Works waste heat supplementary fired boiler that is capable of producing 80 mmbtu of thermal energy per hour. All hot engine exhaust is directed to a mixing chamber where outside air will be added to provide sufficient oxygen to support combustion in the two waste heat boilers. Supplemental fuel, either natural gas or fuel oil is burned with the mixture of exhaust gas and oxygen when needed to respond to hot water heating demands in excess of the amount of heat supplied by the hot engine exhaust. Natural gas is the principal fuel for the waste heat boilers. The boilers can also use No. 6 fuel oil (low sulfur) and better grades.

The high temperature hot water produced by the waste heat boilers is transmitted through a network of specially insulated distribution pipes. Each distribution loop delivers hot water at a different pressure and temperature to comply with the individual thermal energy requirements of the customers serviced by such loop. The pressures of the three loops vary from 150 psig to 375 psig and have flow rates ranging from 550 to 3,100 gallons per minute. The temperature range varies from 120°C (250°F) to 200°C (394°F). A substation containing valves and heat exchangers are located at each of the customers buildings. The substation is the point at which the heat will be drawn off the district heating distribution system. Metering devices are installed at each substation for purposes of determining the amount of heat used by each building.



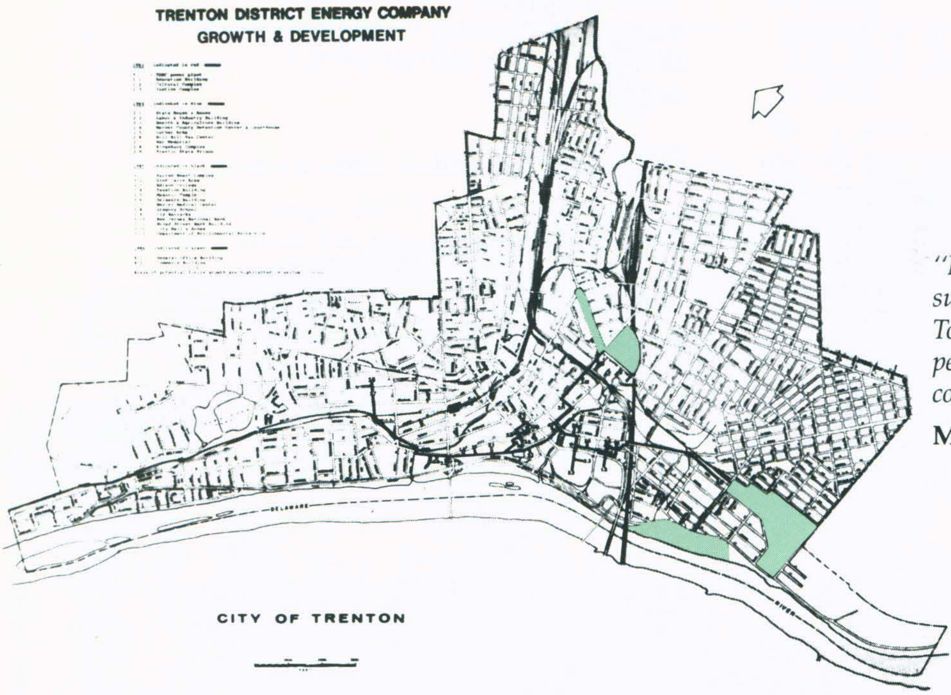
TDEC diesel engines with waste heat boilers

Connected Customers	**Annual Peak (I) (MMBTU)**	**Annual Consumption (MMBTU)**
Justice Complex	40.00	77,390
State House Complex	25.00	32,230
County Detention Center	7.90	21,830
Luther Arms	3.00	5,560
Trenton State Prison	40.00	205,710
Kingsbury Towers	8.00	13,600
Mill Hill Tax Center	1.00	1,460
Health & Agriculture/Labor & Industry	15.00	
Gregory School (3)	1.42	2,230
Glen Cairn Arms (3)	2.58	5,630
Edison College (3)	1.50	1,750
Department of Environmental Protection (3)	0.50	700
Sub-total	145.90	368,110
Contracted Customers		
Mercer Medical Center (4)	20.00	70,040
Delaware Building (4)	1.00	1,500
Broad Street Bank Building (4)	1.58	4,973
City Hall (4)	2.85	5,330
General Office Building	3.00	5,600
Commerce Building	5.00	3,000
Taxation Building	2.50	4,000
Masonic Temple	0.51	770
Sacred Heart Church (4)	0.70	1,520
New Jersey National Bank (4)	2.19	3,497
Sub-total	39.33	100,780
Potential Customers		
National State Bank	3.41	5,440
Architects Housing	1.70	4,464
Department of Motor Vehicle	2.00	6,000
Sub-total	7.11	15,904
Total: Noncoincident	192.34	487,794
Coincident (2)	153.87	

(1) Customer contract annual peak load
(2) Based 80% diversity factor
(3) Customers connected in 1985
(4) Customers to be connected in 1986

Back-Up Systems

The Plant Project design has incorporated several back-up systems in order to assist in ensuring that customer thermal needs are met at all times and to minimize the



"Normally Trenton requires developers to submit the complete plans for a project . . . To lessen this burden on CDC the City will permit it . . . to 'fast track' its plans and construction."

Mayor Arthur J. Holland

effects of temporary shutdowns in service. The diesel engine electric generators and the district heating system can be operated independently of each other. The failure to generate electricity does not preclude production of thermal energy. Similarly, the failure to produce or deliver thermal energy does not preclude the generation of electricity. The boilers are capable of meeting the entire contracted thermal energy demand even in the event that neither diesel engine electric generator is operating. In the event of a complete failure of the engines that generate electricity, electric power to supply the pumps and powerhouse can be supplied by PSE&G. Should a breakdown in the PSE&G grid occur, the Company can supply its electric energy needs from its own diesel engine generators.

Mercer Medical Center and the Trenton State Prison (through the state) have each agreed, to lease their boilers to the Company for use as backup boilers for the Project. The leased boilers can generate enough heat to completely replace one plant boiler. These leased boilers are located at the two extreme ends of the thermal distribution system. In the event of any damage to a section of the thermal distribution system, the damaged section can be isolated and the leased boilers, together with the plant boilers, can continue to supply hot water to undamaged segments. Thus, a break in a loop will not necessarily result in a cut off of thermal energy to all customers beyond the point of the breakdown. The distribution loops contain stored heat in the form of circulating hot water and can carry the peak requirements of all the customers currently under contract for five to seven hours without addition of boiler heat. In the event of a complete failure of the plant boilers, TDEC will be able to bring the leased boilers into service within 1½ hours of the shutdown, thereby minimizing the amount of heat loss experienced by the customers.

The principal fuel for the plant boilers is natural gas, however, the plant boilers can also burn fuel oil. Sufficient fuel oil will be stored at the site to operate the thermal energy system for 24 days in the event of a total interruption of gas supply. If fuel oil were required to be used to fire both the boilers and the diesel engine electric generators, that same fuel oil supply would be sufficient to operate both systems for a two week period. In addition, TDEC will store oil at both Mercer Medical Center and at Trenton State Prison in support of the respective leased boilers. Such supply will be adequate to provide an additional ten days supply of thermal energy to the system. A natural gas supply at Mercer Medical Center will be maintained as an additional fuel supply for the boiler located there.

First Year Operation and Improvements

Since the inception of the Trenton project, Cogeneration Development Corporation (CDC) has pursued a goal of making Trenton District Energy Company (TDEC) into a profitable, highly productive and dynamic district heating system, that will expand its service and improve profitability every year while saving energy. The early years led CDC through a variety of complex and novel steps: developing twenty (20) year thermal and electric contracts, obtaining necessary government permits, selecting conceptual designs, forming a General Partnership (TDEC), negotiating construction contracts, raising $38 million through a variety of financing vehicles, supervising the construction, and begining operations.

1983 was devoted to hiring and training a staff, constructing the power plant and building the first stage of the distribution system. TDEC started 1984 under the control of H. Gordon Stewart, Chief Operating Officer. Mr. Stewart had spent the prior thirteen years at Citizens Utilities, where he was responsible for five electric utilities. TDEC also started 1984 with a plant superintendent and a trained operating staff in place, who operated the plant (first day in service was December 30, 1983) while continuing to supervise the construction of the distribution network and while making an unexpectedly large number of modifications to the power plant.

Power Plant Changes

It was realized in the early months of 1984 that there were a series of design deficiencies, many of which were related to the never-before-tried (in the USA) supplementary fired diesel exhaust heat recovery boilers. Unlike all prior diesel cogeneration projects, where the diesel engine's hot exhaust gas simply has its useful heat recovered, TDEC adds fuel to the exhaust stream, further combusting any unburned hydrocarbons and gaining a significant efficiency advantage (10-15%) over a conventionally fired boiler.

Regrettably, the theory and the practice did not immediately mesh in the TDEC boilers as originally built. It was necessary to make substantial modifications to the boilers so that the operation would more closely match the optimal theory of supplementary fired boilers. All other major plant problems were also corrected in 1984, leaving a power plant that operates as designed.

Contractor Disputes Slow Connections

At the start of 1984, TDEC supplied thermal energy to three buildings but had not yet fully replaced any customer boilers. Disputes over claimed extra costs by TDEC's general contractor slowed further connections in the first five months of 1984 and ultimately resulted in a negotiated settlement with the contractor. At the end of May, the original General Partners invested over $3,148,000 of new equity in TDEC, $2,100,000 of which was paid in settlement for extra work. New site management was provided by the general contractor.

From June through December, construction was sharply accelerated and by year end, TDEC thermal output began to approach projections. As of December 27, 1984, the original contract was substantially completed, with thermal service to all but four of the originally contracted users. The Mercer Medical Center was in the midst of a $30 million expansion, causing delays and a redesign of service to that complex. Two new State Buildings were delayed a year, delaying TDEC's thermal service. Access to the Taxation Building awaited agreement between the State of New Jersey and the bulding's owner on lease rental terms.

Because of the general contractor's substantial overhead, the added costs of these delays were high and projected to grow to a very significant amount. TDEC and the contractor agreed that it was in their mutual interest to delete the delayed work and deem the

Ground breaking ceremonies for TDEC. With shovels from left to right: George Barbour, President, NJ Board of Public Utilities; Arthur J. Holland, Mayor of Trenton; Thomas Kean, Governor of NJ; Tom Casten, President of Cogeneration Development Corp. watches on the right.

One Mayor's Role in Promoting DHC/Cogeneration

One of the key elements of success in the Trenton district heating project has been the enthusiam of the city's mayor, Arthur J. Holland. The Mayor became involved in the concept of developing DHC for his city in 1976 when Trenton applied for, and received, a grant for a feasibility study for an Integrated Community Energy System (ICES). This initial study brought together representatives from several city departments and the private sector.

The results of the initial study showed DHC to be feasible in Trenton. The mayor and other city officials felt that government should not be involved in building and owning such a system unless the private sector was not interested. The city first discussed development with the local utility, which chose not to be involved with the project. In persuing alternate methods of private development, the city opened discussions with Cogeneration Development Corporation.

CDC and the City formed a partnership to promote development of the system; with CDC concentrating on the technical and financial elements, and the city concentrating on the administrative and political decisions.

From his experience with the Trenton system, Mayor Holland has described six areas where the city facilitated DHC development that other communities can adjust to their circumstances:

1. Financing—Because the Trenton system was unique, arranging the financing was difficult. The City provided a $3.8 million loan, and the state issued $14 million in industrial revenue bonds through the New Jersey Economic Development Agency. The City also assisted in lobbying efforts on the federal level to provide a favorable tax environment for DHC development.

2. Customer Contracts—New Jersey state law prohibited local governments from signing contracts longer than three years. To secure financing, TDEC needed 20 year contracts. The city worked with the state legislature to change the law, thus providing the system with secure contracts for several of its major customers.

3. Community Education—The city developed a community education program to educate the public about the benefits of DHC. The one local community that expressed some concern over the development of the system soon was wanting DHC extended to their area.

4. Permits—The city worked with CDC to ease the obtaining of permits and provided data on the city for several federal permits, such as air quality.

5. Lease of Land—The city agreed to lease CDC city owned land for the central plant, thus keeping capital costs down.

6. Fast Tracking for Construction—The city allowed CDC to develop the DHC system in phases rather than present a final plan for the entire system. CDC can submit plans for each phase of development thus "fast-tracking" its construction, and the city is still able to monitor its development.

Mayor Holland has provided another major benefit to the DHC industry in general. His advocacy of the development of the Trenton system, and his familiarizing his colleagues on the economic benefits of DHC, has helped convince other mayors and community leaders to consider the development of DHC in their cities.

construction contract terminated as of December 27, 1984. The contractor was released from all further contractual obligations and general releases were exchanged. TDEC completed minor work and site restoration with its own forces and bid out and procured construction management for completion of the delayed work from local contractors.

In the course of 1984, full thermal service commenced to the State Prison, the State Capitol Complex, the State Justice Complex, the Mercer County Detention Center and Courthouse, and two high-rise apartment complexes. By year-end the connected buildings had a contracted demand of 139.9 million Btu's peak per hour.

Power Plant Operation

The heart of TDEC's plant is the electric generation system from which heat is recovered for sale. Figure 1 shows electrical generation and sales for the first year. Start up problems, normal and abnormal, held down generation in the first three months, but had been corrected by April. An engine turbo-charger failure in late April led to near total outage of electric production in May. After the failure, both engines were inspected, and new control and safety devices installed before electric generation was resumed. Since July 1984, the plant has averaged a 92% load factor, operating within 8% of maximum possible output. Except for normal outages for maintenance, the generation equipment ran at full load 24 hours per day every day during the second half of the year.

Figure 2 shows how monthly thermal sendout increased as more customers were connected during 1984. The turndowns in May/June and September/October reflect moderate weather in which neither heating or cooling was required. The dotted line shows what a normal year's sendout would be with all present users connected the entire year.

Figure 1
TRENTON DISTRICT ENERGY COMPANY
1984 ELECTRICAL GENERATION AND SALES

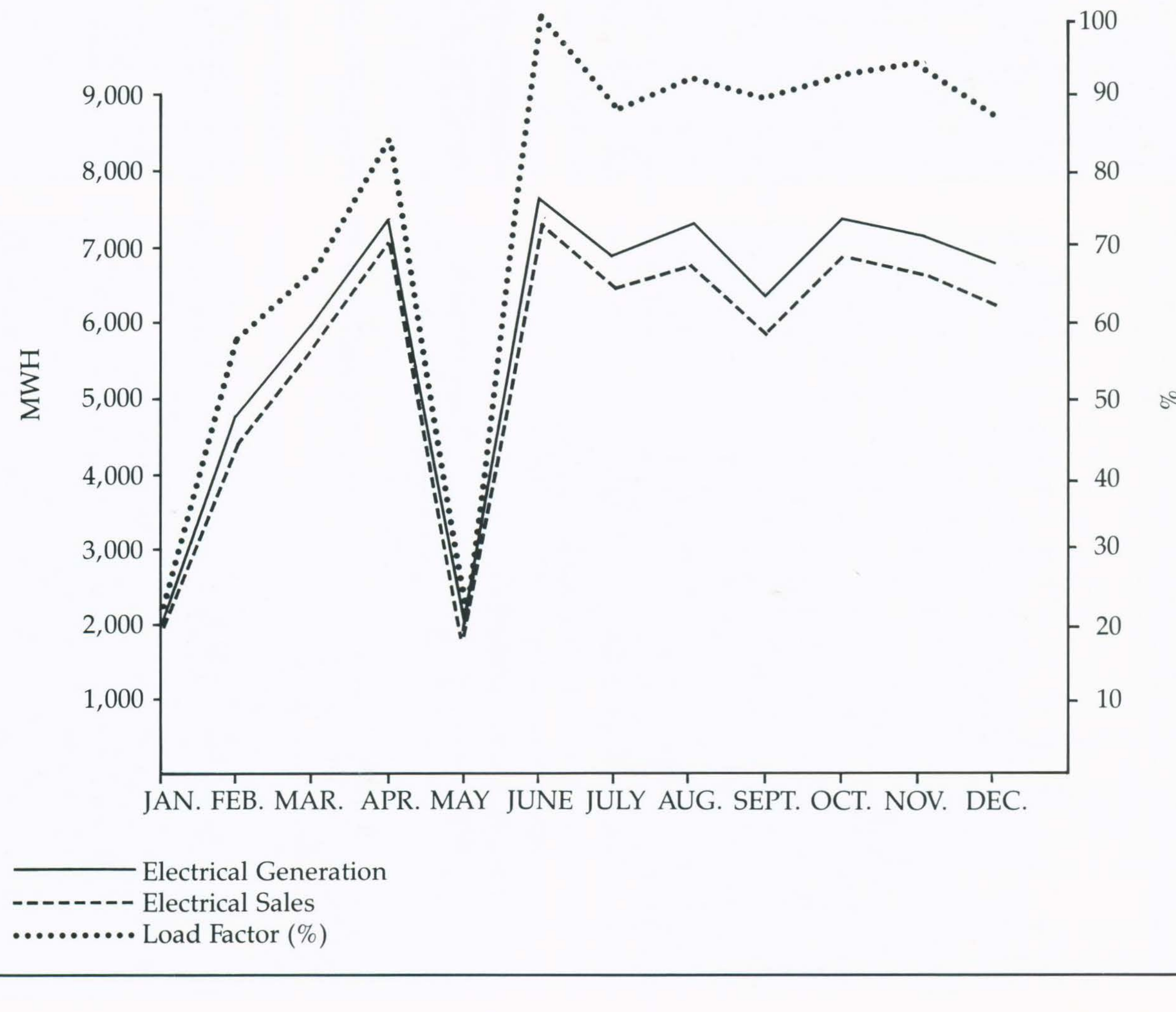
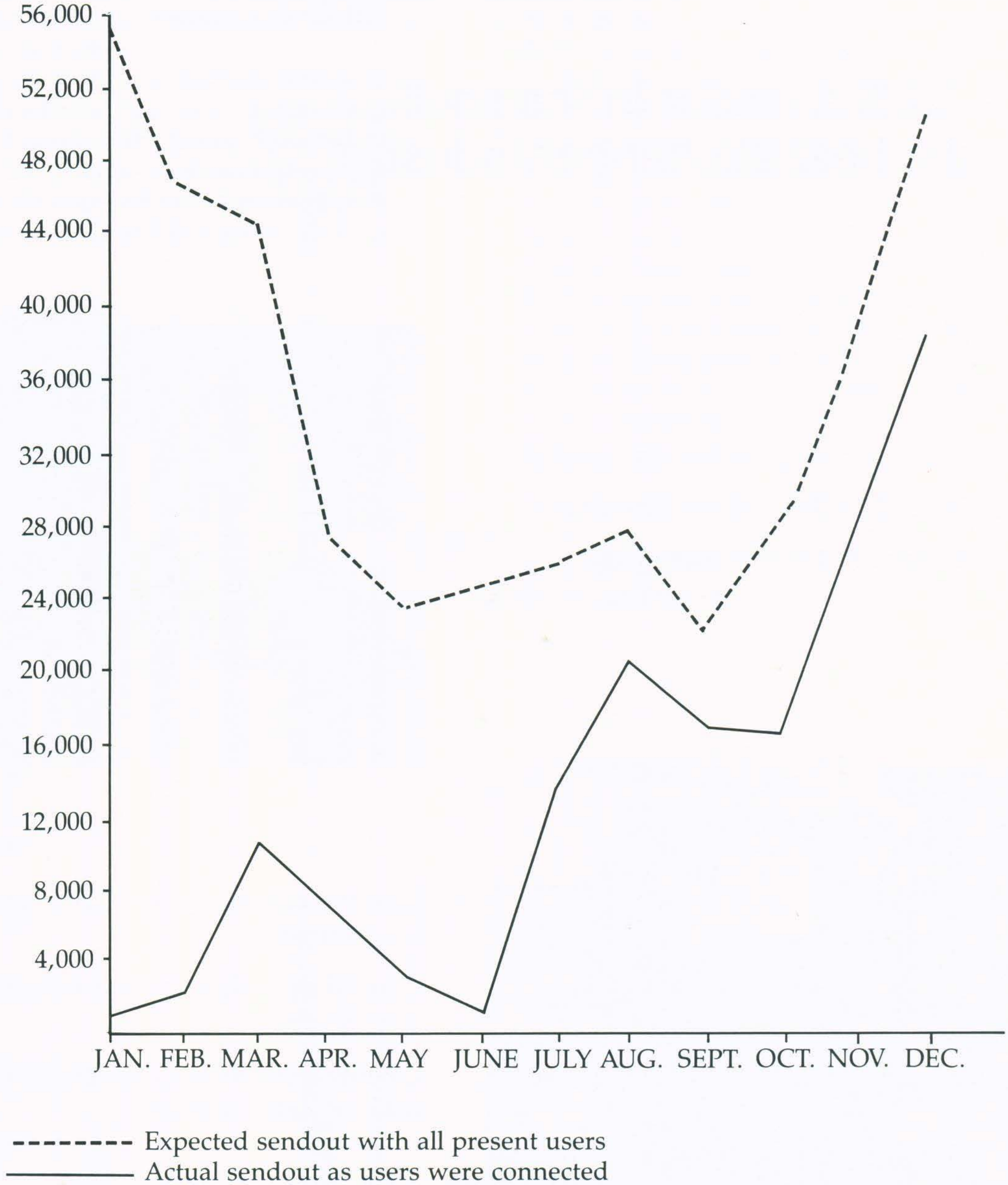


Figure 2
TRENTON DISTRICT ENERGY COMPANY
1984 THERMAL SENDOUT



As thermal sendout increased, more waste heat from the engines was recovered, as can be seen on Figure 3. Heat not recovered either disappears as hot exhaust or is vented with cooling towers, producing no revenue. The increasing amount of recovered heat reflects both greater sale of heat and the improved functioning of the heat recovery boilers.

TDEC profitability is in part a function of its generating efficiency, measured as net heat rate. Net heat rate equals the fuel put into the diesel engines, minus the useful heat recovered, divided by the kiloWatt hours produced. Figure 4 displays the favorable drop in net heat rate from 8500 Btu's/kWh in January of 1984 to 5827 Btu's/kWh in December. By way of reference, central utility generation for the entire USA averages nearly 10500 Btu's per kWh net heat rate. This difference demonstrates the economic rationale for TDEC's existence.

Environmental Impact

During 1984, TDEC sometimes produced a visible, yellow-colored exhaust plume that has concerned TDEC, the Trenton public, and the New Jersey Depart-

Figure 2
TRENTON DISTRICT ENERGY COMPANY
1984 THERMAL SENDOUT

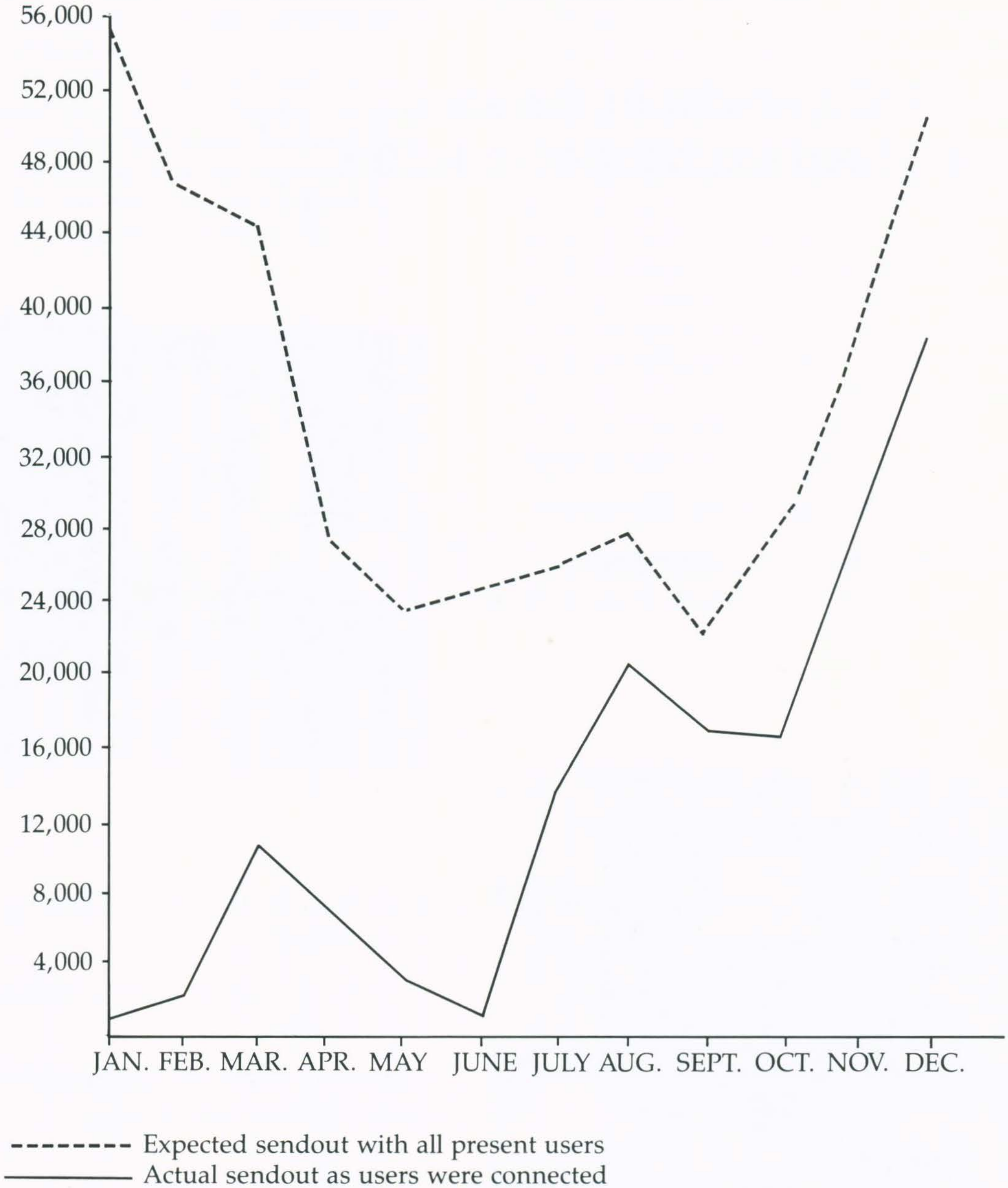


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Figure 3
TRENTON DISTRICT ENERGY COMPANY
1984 RECOVERED THERMAL ENERGY

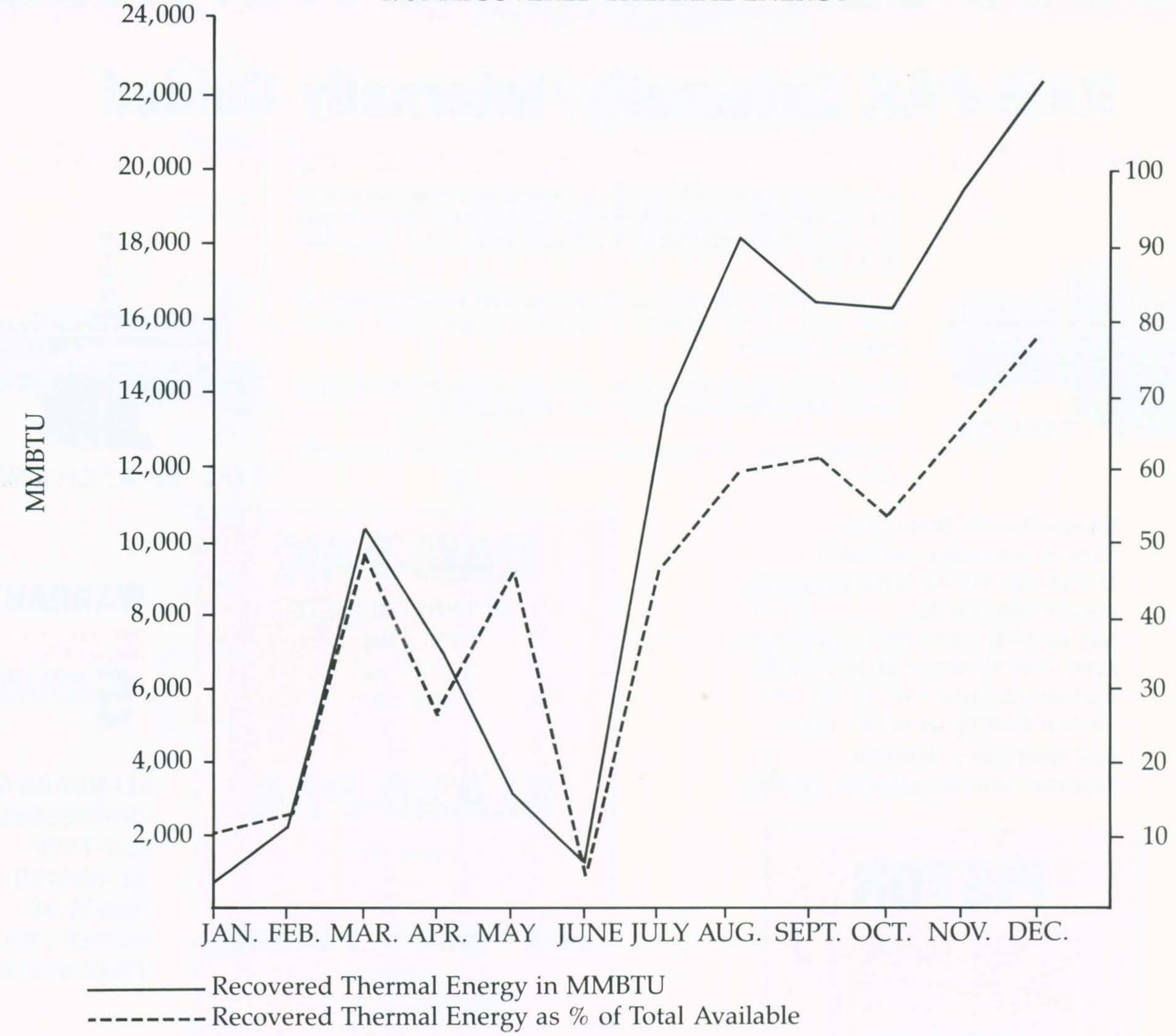
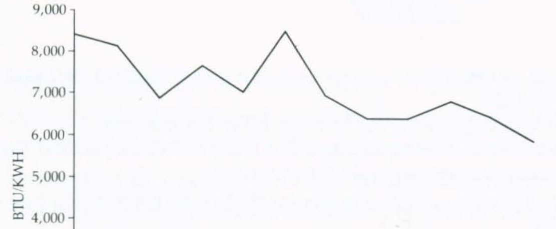


Figure 4
TRENTON DISTRICT ENERGY COMPANY
1984 NET HEAT RATE



ment of Environmental Protection (DEP), which has offices across the street from TDEC's power plant. TDEC has been operating permissibly under a temporary permit. Two 1984 stack tests showed levels of unburned hydrocarbons and carbon monoxide that, while measured in parts per million, were above the levels allowable for TDEC to secure a permanent operating permit.

TDEC worked closely with the DEP, made numerous plant changes and reduced the offensive elements of the exhaust. The most significant finding over the year was that TDEC produced cleaner exhaust as thermal loads and supplementary firing increased. Consequently, they are aggressively moving forward to connect new users so as to have clean, clear, nonvisible exhaust at all times of year. The DEP has mandated this expansion as a compliance step, and happily economics and environmental concerns match.

Fuel Purchases

TDEC is by design totally capable of dual operation, using natural gas and/or No. 2 diesel oil to fuel the engines and using either natural gas or No. 6 oil to fuel the boilers. The gas supply from PSE&G was without interruption during 1984. The engines burn roughly 5% oil for pilot fuel and burn 100% oil for an hour every day in order to clean and lubricate the injectors. Number 6 oil was not burned during 1984.

In August of 1984 with the blessing and encouragement of the Board of Public Utilities, Public Service Electric & Gas Company offered a special "Cogeneration Incentive Gas" rate (CIG) for engine gas only that would lower TDEC's fuel costs by roughly $1,300,000 per year. TDEC would, by purchasing CIG rate gas lower its electric revenues by $900,000 per year, leaving roughly $400,000 savings to TDEC's thermal customers. In order for TDEC to accept the new gas contract, thermal customers had to agree to an amendment to their contracts, which lowered their overall costs due to TDEC's lower fuel cost. There was no net financial impact to TDEC of this change.

1985 Accomplishments and Future Developments

With the thermal connections made in November of 1984, TDEC passed the break even level of operations. At that level of hookups, TDEC projected a net cash flow after debt service of roughly $500,000 per year. But 1985 was a year of expansion of the system.

In 1985 TDEC sold completion bonds that permitted the laying of 6,168 additional feet of piping. They added four new customers: the New Jersey Department of Environmental Protection Building, approximately 400,000 square feet of space; the Glen Cairn Arms, a 101 unit apartment building; the Gregory School, a new school built without a boiler; and Edison College, a state operated continuing education college.

In 1985 TDEC generated 95,634 MW of electricity and sold 89,347 MW to the local electric utility. The district heating system sold 283,607 mmBtu's of thermal energy to its customers.

In 1986 TDEC will be adding six additional customers to the system representing an additional 39 mmBtu/peak: the Mercer Medical Center; Trenton City Hall; Broad Street Bank Building and New Jersey National Bank Building, both 14 story office buildings; the Deleware building and the Sacred Heart Church, the oldest Catholic church in New Jersey.

Cooling Development

Plans are underway to develop a chilled water system for the customers of TDEC. Because it is a cogeneration system, the diesel engines are running year round and the various pieces of equipment are generating waste heat at various temperatures. The system will utilize a variety of enthalpy levels at the plant to power absorption chillers. The projected loads are 8,000 peak ton/hour and 7.5 million annual ton/hour. To effectively use the diesel generators the system will incorporate chilled water storage tanks holding 3 million gallons that can be generated off peak.

A motivating factor behind the development of the cooling system is that the state is in the process of rehabilitating their buildings and planning to take out the various air conditioners in the buildings. By being able to connect to a cooling system, the state will save over a half a million dollars in capital costs.

Since the state needs the system in by June of 1987 plans are to break ground as soon as weather permits in 1986. The pipes will be laid parallel to the existing hot water pipes and TDEC is in the process of aquiring land next to the plant for the chilled water storage.

The Trenton District Energy Company has defied many sceptics by showing that district heating and cooling presents a viable opportunity for development today. It took major efforts on the part of the public sector working with the private developer to make it work. Without the cooperation of the city and state in assisting in development, and in becoming major customers, TDEC would not be the successful venture that it is.

New Pipe Being Laid For Expansion of the Trenton System