Energy

CONSERVATION

URBAN INTEGRATED INDUSTRIAL COGENERATION
SYSTEMS ANALYSIS

Phase II, Final Report

January 1984

Work Performed Under Contract No. FG02-80CS40337

City of Chicago
Department of Planning
Chicago, Illinois

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

5/1/84 mLR ② DR- 9-4
DOE/CS/40337-15
(DE84007189)

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A14
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

URBAN INTEGRATED INDUSTRIAL
COGENERATION SYSTEMS ANALYSIS
PHASE II FINAL REPORT

Report Prepared Under the
U.S. Department of Energy Grant No. DE-F02-80CS40337

City of Chicago
Department of Planning

January 1984

PROJECT DESCRIPTION

The project "Urban Integrated Industrial Cogeneration Systems Analysis" addresses the identification and resolution of institutional, legal and economic issues of cogeneration in the urban environment. It also focuses on technical matters particularly, including the thermal-economic analysis of cogeneration within the context of regulation, financing, design, and optimization. The work is applied using a case study approach to cogeneration opportunities identified by a survey of industries and institutions in the City of Chicago in cooperation with Peoples Gas Company and Commonwealth Edison Company. The project attempts to bring to the attention of the industrial-commercial sector the opportunities and benefits of cogeneration in conserving energy and stimulating economic development.

EXECUTIVE SUMMARY

Cities with local economies dependent upon the viability of energy intensive industries must find ways to encourage economic growth while holding down the energy-related costs of doing business. Cogeneration is one promising technology that provides significant opportunities for reducing energy costs. Through effective planning, cogeneration can also serve as an incentive for industrial growth in dense urban areas. Furthermore, cogeneration facilities can be designed to use alternative fuels, such as municipal refuse, which would benefit local governments by providing revenue-producing solutions to their growing waste disposal problems. Through the Urban Integrated Industrial Cogeneration Systems Analysis (UIICSA), the City of Chicago embarked upon an ambitious effort to identify and measure the overall industrial cogeneration market in the city and to evaluate in detail the most promising market opportunities. This report discusses the background of the work completed during Phase II of the UIICSA and presents the results of economic feasibility studies conducted for three potential cogeneration sites in Chicago.

Phase I of the UIICSA involved the identification of industrial "sites" which could be attractive for cogeneration development, and the ranking of these sites based primarily on their technical potential. The Phase I Final Report consists of six volumes which discuss the following factors related to

cogeneration development: site selection and evaluation, regulatory and tax aspects, environmental aspects, assessment of technologies and alternative fuels and industrial cogeneration potential in Chicago through the year 2000.

Phase II of the UIICSA focused on the feasibility of cogeneration at the three most promising sites: the Stockyards and Calumet industrial areas, and the Ford City commercial/industrial complex. Each feasibility case study considered the energy load requirements of the existing facilities at the site and the potential for attracting and serving new growth in the area. Alternative fuels and technologies, and ownership and financing options were also incorporated into the case studies. Finally, site specific considerations such as development incentives, zoning and building code restrictions and environmental requirements were investigated.

The results of the three case studies suggest that significant potential for cogeneration development does exist at the three selected sites. This potential is, of course, largely dependent upon future energy prices and the continued economic viability of the industrial firms and commercial establishments that currently exist at the sites. Based on the findings of the case studies, two types of cogeneration facilities are deemed to be the most viable: refuse-fired incinerators with cogeneration for the Stockyards and Calumet sites, and a natural gas-fueled

gas turbine system at the Ford City site. The economic feasibility of the incineration facilities is enhanced by the potential availability of publicly-assisted debt in the form of Industrial Development Bonds. In the case of the Ford City site, the economic potential of the proposed system is highly dependent upon the relative prices of natural gas and electricity over the next five to ten years, with the attractiveness of cogeneration increasing as electricity prices rise at a faster rate than natural gas prices.

It is recommended that the Stockyards and Calumet areas be considered as sites for future incineration/cogeneration facilities, particularly in light of the recent designation of these areas as Enterprise Zones. In addition, an attempt should be made by the City to identify and attract to Chicago industries particularly well-suited for cogeneration, and to coordinate the location of these firms with plans for the development of low-cost energy supply systems.

With respect to the Ford City complex, it is recommended that this site also be considered for the development of a central cogeneration facility. The substantial energy demand that already exists at the site could be increased by encouraging

new tenants to locate within the complex with the incentive of reduced energy costs or by expanding the site to include major energy users located nearby. Further, changes could be made to the existing end-use technologies to balance the energy loads and thereby increase the attractiveness of cogeneration at the site.

The Department of Planning will continue to assess the potential for cogeneration as part of the City's comprehensive energy program. These research efforts will be coordinated with the Departments of Economic Development, Public Works, and Streets and Sanitation in order to ensure that public and private developments will be considered in light of the City's long-range energy plans and waste disposal strategies. The City will continue its work in disseminating information about cogeneration to potential users of these systems. Moreover, the City will continue to act as a facilitator between potential users of cogeneration systems and local utilities, regulatory agencies, financial institutions and public and private development organizations in an effort to identify opportunities for cogeneration and to promote the development of viable projects in Chicago.

TABLE OF CONTENTS

	<u>Page</u>
PROJECT DESCRIPTION	ii
EXECUTIVE SUMMARY	iii
I. INTRODUCTION	
Background	1
Project Objectives	1
Scope of Phase II	3
II. COGENERATION, SITE SELECTION AND DEVELOPMENT CONSIDERATIONS	
Selecting Potential Cogeneration Sites	5
Technology Assessment	9
Local Development Regulations	12
Zoning	
Building Codes	
Development Incentives	17
Chicago Enterprise Zone Ordinance	
Illinois Enterprise Zone Act	
III. ENVIRONMENTAL ASPECTS	
Scope of Environmental Assessment	22
Air Quality Regulations	24
Application of Regulations to Proposed Sites	27
Wastewater and Solid Waste	30
Other Environmental Considerations	31
IV. ALTERNATIVE OWNERSHIP AND FINANCING OPTIONS	
Overview	34
Public Ownership	35
Financing Options	
Revenue Bond Financing	
Tax Considerations	

Table of Contents (continued)

	<u>Page</u>
Private Ownership	38
Financing Options	
Government Use Restriction	
Industrial Development Bonds	
Tax-Oriented Leasing by a Third Party Investor/Owner	
Summary	47
V. FEASIBILITY CASE STUDIES	
Scope of Case Studies	48
Stockyards	50
Site Considerations	
System Design	
Economic Analysis	
Calumet	60
Site Considerations	
System Design	
Economic Analysis	
Ford City	74
Site Considerations	
System Design	
Economic Analysis	
VI. SUMMARY AND CONCLUSIONS	
Overview	88
Summary of Results	89
Stockyards	
Calumet	
Ford City	
Conclusions	92
REFERENCES	96

Table of Contents (continued)

APPENDICES

- 1.1 UIICSA Phase I Final Report, Volume 1, Project Overview
- 2.1 Cogeneration Seminars and Energy User Survey
- 3.1 Air Pollution Emission Calculations
- 4.1 Revenue Bond Financing Structure
- 4.2 Third-Party Tax Lease Financing Structure
- 5.1 Case Study of Refuse-Fired Cogeneration for the Stockyards Industrial Area
- 5.2 Case Study of Refuse-Fired Cogeneration for the Calumet Industrial Area
- 5.3 Industrial Cogeneration Feasibility Study: Ford City Commercial/Industrial District

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Emission Estimates for Two 150-TPD Basic Incinerators	28
2	Thermal Performance of Two Refuse-Burning Modular Incinerators for Cogeneration	54
3	Summary of General Economic Parameters for Stockyards and Calumet Site Analysis	56
4	Economic Performance of Two Refuse-Burning Modular Incinerators for Cogeneration Operated at Full Available Capacity Without Credit for Conventional Equipment	57
5	Effects of Financing for Two Refuse-Burning Modular Incinerators for Cogeneration With and Without Sales to Utility	59
6	Thermal Parameters for Modified Reheat Incinerator with Cogeneration for Republic Steel Steam Supply	66
7	Economic Performance of Refuse-Burning Modular Incinerators with Cogeneration for Republic Steel Without Credit for Conventional Equipment	67
8	Effects of Financing for Five Modified Refuse-Burning Modular Incinerators with Cogeneration for Republic Steel Only, With and Without Sales to Utility	68
9	Thermal Performance for Refuse-Burning Modular Incinerators with Cogeneration for Calumet Area Including Republic Steel, Cargill and General Mills	71
10	Economic Performance of Refuse-Burning Modular Incinerators with Cogeneration for Calumet Area Operated Without Credit for Conventional Equipment	72
11	Effects of Financing for Refuse-Burning Modular Incinerators with Cogeneration for Calumet Area	73

List of Tables (continued)

<u>Table No.</u>		<u>Page</u>
12.1	Gas Turbine Performance	79
12.2	Gas Turbine System Efficiency	79
13	Economic Parameters for Ford City Feasibility Analysis	82
14	Capital Cost of Cogeneration System Options	84
15	Real Internal Rate of Return for Ford City Cogeneration System	85

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	Site Selection and Evaluation Methodology	6
2	Potential Cogeneration Development Site	8
3	Potential Cogeneration Development Areas	11
4	Chicago Enterprise Zone II	19
5	Chicago Enterprise Zone III	20
6	Distribution System for Stockyards Area	51
7	Calumet Area Site for Refuse-Fired Cogeneration Plant	61
8	Modified Modular Refuse Incinerator and Cogeneration Plant for Republic Steel Company Steam Supply	63
9	Ford City Shopping Center and Industrial Park	76

I. INTRODUCTION

Background

Over the past decade, energy intensive industries have been hit hard by rising production costs due largely to escalating fuel prices. Cities with local economies dependent upon the viability of these industries are therefore seeking ways to encourage economic growth through the development of innovative energy plans. One of the more promising techniques for improving industrial energy productivity is cogeneration, which refers to the simultaneous production of electrical (or mechanical) power and process heat with on-site facilities. Planners are now looking to cogeneration not only as a means for achieving significant savings in energy costs but also as a key element in the revitalization of urban industrial areas. Cities such as St. Paul, Trenton, Baltimore and Washington, D.C. have undertaken community energy projects, but Chicago has been somewhat unique in its attempt to integrate cogeneration into its industrial development plans for the city. This report will discuss the objectives of Chicago's industrial cogeneration project and will present the results of Phase II of this effort.

Project Objectives

The primary objective of the cogeneration study is to identify potentially viable projects which the City can help to implement. Success of the project is largely dependent upon the City's "brokering" role between potential users of cogeneration

systems and the local utilities, financial institutions, equipment suppliers, regulatory agencies and the public and private development community to facilitate the identification of opportunities for cogeneration and to promote the development of viable projects in Chicago. Toward this end, the City sponsored a series of cogeneration presentations and seminars for industrial managers and development organizations, commercial developers, investment bankers, local government officials and others interested in cogeneration development in Chicago.

In addition to the general educational efforts of the project, the City contacted nearly 200 industrial firms and other energy-intensive facilities located within potential cogeneration development areas and personally visited 20 of these firms to discuss the project goals and to solicit participation in the study. Through this effort, and with the cooperation of the Illinois Institute of Technology and the Energy Resources Center of the University of Illinois at Chicago, the City was able to identify not only the most likely industrial sites for cogeneration development but also nearby commercial and institutional facilities which could be served by central cogeneration systems. This work was largely completed and documented during Phase I of the UIICSA, along with the assessment of alternative cogeneration technologies and fuels, environmental considerations, tax and regulatory incentives and the overall potential market for cogeneration in Chicago through the year 2000.¹

Scope of Phase II

Phase II of the UIICSA has focused on the technical and economic feasibility of central cogeneration at three specific sites in Chicago: the Stockyards and Calumet industrial areas and the Ford City commercial/industrial complex. These three sites were identified as showing the greatest promise for development, and the analysis proceeded with the active participation and support of owners and operators of the industrial firms and of other energy-intensive facilities within these sites. The case studies developed for these areas take into consideration the particular energy load requirements of the facilities now existing at the sites and also the potential for new growth in the areas so that the systems can be expanded to meet future energy demands. Alternative technologies and fuels have also been considered and incorporated into the case studies.

The following report will discuss the site selection process and the technology assessment that led to the identification of the three case study sites. In addition, site specific considerations, including development incentives, zoning and building code restrictions and environmental regulations will be discussed. The report also describes alternative ownership and financing options which may be utilized in the development of cogeneration facilities in Chicago. Finally, the Stockyards, Calumet and Ford City case studies are described and the results are summarized. The complete feasibility studies are included as appendices to the report.

The cogeneration project research team, which includes the Department of Planning staff and technical advisors from the Illinois Institute of Technology and the engineering consulting firm of Fauske and Associates, are currently working with the Departments of Economic Development, Public Works and Streets and Sanitation, as well as representatives from the industrial, commercial and institutional facilities within the three select sites, to coordinate plans for public and private development in these areas. These include efforts to recruit new industry to Chicago, plans for the construction or rehabilitation of a new incinerator and various infrastructure improvements within the City. Through these efforts, the City is attempting to incorporate innovative, long-range energy planning into the urban development process and thereby to take advantage of the economic benefits that technologies such as cogeneration can provide to both the public and private sectors of Chicago.

II. COGENERATION SITE SELECTION AND DEVELOPMENT CONSIDERATIONS

Selecting Potential Cogeneration Sites

Previous cogeneration studies have primarily focused on specific industries and single, large energy-intensive firms. However, it is also possible to screen and evaluate "sites" within a larger geographical context, such as a city or a metropolitan area for the purpose of measuring cogeneration potential. One of the initial steps undertaken in the site selection process was the development of an inventory of industrial firms and other energy-intensive facilities with cogeneration potential in Chicago. Toward this end, a comprehensive list of 111 energy intensive industries, identified by Standard Industrial Classification (SIC) code, was compiled by project researchers.² These were separated into two groups: primary thermal users, whose thermal energy was considered to be of a baseload character; and co-located facilities, whose thermal energy requirements were more likely to be for space heating. This latter group was included because of the close location of these facilities to energy intensive firms which could serve as the core of the potential cogeneration systems.

The methodology used to identify and evaluate potential cogeneration sites in Chicago consisted of three major phases:

Figure 1

SITE SELECTION AND EVALUATION METHODOLOGY

1. Description of the geographical distribution of industrial firms, commercial facilities, public buildings and institutional complexes in Chicago with cogeneration potential,
2. Definition of the energy use patterns for these firms and facilities and
3. Selection and evaluation of candidate sites particularly well-suited for industrial cogeneration.

The inventory of firms and facilities, complete with energy use information provided by the local utilities, was screened for the purpose of identifying potential cogeneration sites for further study. Energy use characteristics served as the primary screening criteria, with secondary considerations given to the geographical distribution of firms and facilities in a given area. Thirty-four sites, consisting of approximately 300 firms and facilities, were selected as the most favorable for further evaluation.

The final stage of the site selection process involved the profiling and evaluation of potential cogeneration sites (Figure 2). The sites were evaluated according to criteria related to the requirements of particular cogeneration technologies and to the opportunities for industrial development. The objective of this task was to evaluate and compare the potential sites and to identify the most promising sites for further detailed technical and economic feasibility studies during Phase II of the study. The criteria applied to the site evaluation included: factors describing various measures of energy consumption; average distance among facilities within the site; types of facilities located at the site; the manner in which energy is used by those

Figure 2

POTENTIAL COGENERATION DEVELOPMENT SITE

facilities; state-of-repair and distribution of existing energy systems such as central steam facilities; amount of vacant land located within or near the site; accessibility of the site to major transportation thoroughfares; and plans for industrial, commercial or other public development in the area.

A hierarchial, linear-weighted model was used to determine the relative suitability of the 34 candidate sites. Each of the components was first transformed, or mapped, on a scale which represented critical values for the evaluation. Following the application of the site evaluation procedure of the 34 candidate sites, it was possible to rank the sites and to determine a priority for later feasibility studies.

Technology Assessment

In conjunction with the site selection process, another major activity undertaken during Phase I of the study was the technology assessment carried out by the Illinois Institute of Technology.³ Particular attention was given to the thermal-economic aspects of cogeneration and alternative fuels as they affect the feasibility of projects in light of contemporary legislation and financial arrangements. The approach was founded on the identification of technologies and relevant industries by previous U.S. Department of Energy studies. However, recognition was given to local and site-specific conditions as well as recent legislation, including the National Energy Act and the Tax Equity and Financial Responsibility Act of 1982.⁴ Technologies included fired boilers using steam turbines and fueled by natural gas, low-sulfur coal or refuse, and dual-fuel diesels and gas turbines

employing natural gas. Relevant industries in Chicago are varied but predominate within the food processing industry.

The approach to the economic assessment was based on the rate of return on incremental investment being at least a "threshold" or "hurdle" value. In order to reduce the uncertainty of general inflation, real dollars of constant purchasing power were employed. The favorable effects of alternative financing, including debt financing and leveraged leasing, were also studied, and the analysis yielded levelized annual savings which can be translated into product cost reductions.

A series of case studies was performed including a single direct-heat user, a small single steam user, a central refuse-fired cogeneration plant, a medium central cogeneration plant and two commercial facilities. A "generic" study was also performed using typical parameters in such a manner that the user requirements for viable technologies were determined.⁵ Once these requirements were defined, it was possible to reduce from 34 to 21 the number of potential cogeneration sites identified in previous phases of the project.

Following an extensive effort to solicit participation and detailed energy use data from firms and facilities included in the potential cogeneration development sites, five sites were selected as candidates for Phase II feasibility studies (Figure 3, also see Appendix 2.1). The main difficulty in making this determination was that of organizing users into a single system of sufficiently small energy distribution distance. Many other

sites could become viable if a sufficiently large thermal load is added in the form of new users. An additional consideration was the potential impact that a refuse-fired facility would have on Chicago's current and future refuse-disposal systems. In the Department of Public Works' recent Chicago Resource Recovery Study, there is some consistency in the general areas identified as possible sites for new or rehabilitated municipal incinerators, and cogeneration is one of the several options currently under consideration by City officials.⁶

Local Development Regulations

Most local governments have at their disposal regulations which govern the development of all new construction projects. Based legally on local ordinances and codes, these regulations set forth the requirements for the use of land and structural specifications for the development. Like all new construction projects, the development of a cogeneration facility must meet the zoning and building code requirements of the local government prior to actual construction. Although these regulations may vary from city to city, they establish a framework to follow in the development of cogeneration projects.

As part of the development review process, the zoning and building code requirements related to the physical development of cogeneration facilities in Chicago were assessed. The zoning requirements for cogeneration facilities will vary according to the equipment and fuel used at the site and the permitted uses

within specific zoning districts as illustrated in the site reviews of the Stockyards, Calumet and Ford City included in this section.

Zoning

The Chicago Zoning Ordinance regulates the development of cogeneration facilities within the city's boundaries. The ordinance consists of two parts, the map and the text. The map geographically indicates the specific boundaries of the use districts while the text verbally itemizes the specific requirements within each use district. The ordinance also identifies the permitted uses of land and buildings within specific zones as well as the height, bulk and lot size of the buildings and the density of land use. Other areas of regulation include parking, signs and performance standards.

The three proposed sites were reviewed to determine the feasibility of developing cogeneration facilities within the existing zoning districts. There are two types of cogeneration facilities proposed: refuse-fired incinerators for the Stockyards and Lake Calumet sites and a gas-fired turbine for the Ford City site. The Chicago Zoning Ordinance provides for the development and use of these types of facilities only in areas designated as manufacturing districts. The use of these types of facilities would not be considered an ordinary permitted use but could be allowed as a special use. A special use is a type of development that, because of its unique characteristics, cannot be properly classified in any particular zoning district without consideration, on a case by case basis, of the impact of this use

upon adjacent land use and of the public need for the particular use at the specific location.

As set forth in the Chicago Zoning Ordinance, the Zoning Board of Appeals reviews special uses that are not generally permitted within particular zoning districts. The Board of Appeals has the responsibility of reviewing all applications for special use variations at scheduled public meetings. Upon their review of the applications and the recommendations of the Chicago Department of Planning, the Board will approve or disapprove the request for a special use. Once the Zoning Board of Appeals approves the special use application, the cogeneration facility proposal can be reviewed as to its compliance with building code regulations.

As indicated in the following site reviews, the potential for developing cogeneration facilities within the existing zoning district and under current regulations was found to be very favorable.

Stockyards

The Stockyards site, located at 1400 West Pershing Road, is designated as a Heavy Manufacturing District. The type of cogeneration facility under consideration at this site would utilize two refuse-fired modular water-wall incinerators and would be located at the existing City refuse transfer station (formerly the Southwest Incinerator). Under current zoning regulations, a cogeneration facility of this nature would be compatible with allowed special uses in heavy manufacturing districts. The presence of the existing, though nonoperational,

incinerator supports the conclusion that this type of use is allowed and compatible with other uses in the surrounding area. However, the facility would be required to operate in accordance with the manufacturing district's performance standards which govern such factors as allowable noise levels, the emission of toxic matter and noxious materials, the storage and utilization of flammable or combustible products and operations producing glare or heat. Another possible limitation of the site is the special review process required for zoning approval which may cause delays in the development of the project.

Lake Calumet

The Lake Calumet site is located adjacent to the Republic Steel Plant, between 111th and 144th Streets and west of the Calumet River. The area is also designated as a Heavy Manufacturing District. Like the Stockyards, the facility proposed for the area is one which utilizes two refuse-fired water-wall incinerators. The development of such a facility in the Calumet area would be compatible with associated industrial uses allowed in heavy manufacturing districts. The incineration of waste products would not be uncommon in this district, since the Calumet area now includes a number of facilities which burn industrial wastes. However, as will be discussed in the environmental section of this report, the public perception of Calumet as a growing waste dump site may pose problems for new facilities to be developed here. Other possible limitations of

the Calumet site, similar to that of the Stockyards area, would be requirements for the facility to operate in accordance with the manufacturing district's performance standards and possible project delays due to the special review process.

Ford City

The cogeneration facility under consideration for the Ford City site would be located in the general area of 72nd Street and Kostner Avenue (4400 West). This site is designated as a General Manufacturing District. The facility proposed for the site would employ a gas turbine-generator cogeneration system fueled with natural gas. The permitted use of this type of facility is questionable. It most likely would be considered a special use and would be reviewed by the Zoning Board of Appeals. However, a project of this nature appears to be compatible with associated uses allowed in general manufacturing districts and would have a minimal effect on the environment, particularly in comparison with a refuse-fired system. It is doubtful whether a refuse-fired facility would be approved for this area due to the close proximity of residential and commercial uses in the area and probable conflicts with performance standards set for these districts.

Building Codes

The Chicago Building Codes regulate the physical development of cogeneration facilities within the city boundaries. The codes are legal documents that set forth requirements to protect the public health, safety and general welfare as they relate to the construction and occupancy of physical structures. This is

accomplished by establishing minimum acceptable conditions for matters found to be in need of regulation. Topics generally covered are exits, fire protection, structural design, plumbing facilities, lighting and ventilation and electrical installation.

The Chicago Department of Inspectional Services is responsible for reviewing all development plans to ensure their compliance with building code regulations. Plans that do not meet the minimum code specifications must be amended in compliance with code standards. Once all portions of the development plan have been determined to meet code specifications and requirements, building permits for the actual construction of the development will be approved and issued.

During the actual construction of a cogeneration facility inspectors from the Department of Inspectional Services would visit the site to ensure that the development is being built according to code specifications and as proposed by the original development plans. When the development is completed, the Zoning Department would issue a Certificate of Occupancy. The cogeneration site would then be continually monitored by the local, state and federal officials to ensure that its use and performance is in compliance with all levels of government regulations.

Development Incentives

An added incentive for cogeneration in Chicago is the recent designation of "enterprise zones" which encompass two of the sites under consideration for cogeneration development. The enterprise zone concept focuses on the relief of economically

depressed urban areas through government sponsored private initiative, and it is based on the expectation that the revitalization of a business community will produce a growth in jobs and an overall improvement in the quality of urban life in these areas.⁷ In Chicago, new and existing businesses within the Stockyards and Calumet areas are eligible for special tax incentives and relief from regulatory burdens under state and local enterprise zone legislation. The Stockyards site is part of Zone II which is bounded approximately by 31st Street, Western Avenue, 51st Street and Cottage Grove (Figure 4). The Calumet site is part of Zone III which generally includes Lake Calumet Harbor and the area paralleling the Calumet River (Figure 5).

Chicago Enterprise Zone Ordinance

The Chicago Ordinance designates the Commissioner of Economic Development as a Zone Administrator who has the authority to grant zoning variances and to recommend building code modifications which would enhance development within an enterprise zone. The Ordinance also allows for various city tax credits, including an exemption from the one percent sales tax on building materials purchased for remodeling, rehabilitation and new construction within an Enterprise Zone. Also, retailers within the city limits who sell building materials for use within the zone are eligible for a credit refund on those sales to recover the amount of tax paid under the Municipal Retailers Occupational Act. In addition, the transfer of a title to real property located within a zone is exempt from the Chicago Transaction Tax.

Figure 4

CHICAGO ENTERPRISE ZONE II

Figure 5

Illinois Enterprize Zone Act

Additional benefits are provided under the Illinois Enterprise Zone Act. Loans are available through the Illinois Industrial Development Authority for businesses to locate or expand in an Enterprise Zone. State income tax deductions are allowed for dividends paid by a corporation which conducts business solely within a zone, and a business locating or expanding in an Enterprise Zone is eligible for a state income tax credit for investments in qualified property. Financial institutions may deduct the amount of interest income which they receive from loans given to people who successfully claimed investment tax credits. Also, retailers who make a sale of building materials to be incorporated in a zone are exempt from the four percent State Retailers Occupation Tax. Further, taxes on real property within a zone can be abated by an order from any taxing district.

The incentives provided under the Enterprise Zone legislation enhance the opportunities for developing cogeneration facilities in the Stockyards and Calumet areas. The sales tax exemptions would be beneficial for purchasing materials needed to construct a cogeneration facility. In addition, income tax deductions may encourage existing industry to expand their facilities and may persuade new industries to locate in these areas.

III. ENVIRONMENTAL ASPECTS

Scope of Environmental Assessments

In addition to the local zoning and building code restrictions outlined in the previous section, a cogeneration facility may fall under other regulations intended to limit the potential adverse effects of the facility on the local environment. The environmental affects of cogeneration will vary according to the technology and fuel employed by a particular facility. However, potential environmental impacts and applicable regulations can reasonably be determined in advance through an assessment of the facility's design and location. The primary environmental concern is the emission of air pollutants resulting from the burning of fossil fuels or municipal refuse. Other environmental concerns include waste water discharge, solid waste disposal and potential negative adverse effects on the social environment within communities where cogeneration facilities are located.

Cogeneration facilities may be subject to environmental restrictions, particularly air quality regulations. The most important piece of environmental legislation pertaining to fossil fuel or refuse-burning facilities is the Clean Air Act. The Illinois Environmental Protection Agency (IEPA) is the primary agency responsible for administering regulations pursuant to the

Clean Air Act in Illinois. Most environmental regulations are enforced through local and state permits which are required for the construction and operation of air pollution sources or modifications to sources.

During Phase I of the cogeneration study, the Illinois EPA calculated emission estimates for five alternate cogeneration systems which were being considered for the Ford City site in Chicago. These estimates were based on compliance with applicable emission standards. Using these estimates, the applicability of air quality rules for major sources or major modifications to the five systems were summarized. It was concluded that with the proper utilization of air pollution control equipment to comply with emission standards and the availability of exemptions from local restrictions, the environmental regulations should not inhibit the development of cogeneration facilities in Chicago.⁸

In conjunction with the feasibility case studies conducted during Phase II of the cogeneration study, the environmental effects of a refuse-fired cogeneration facility were examined for those sites under consideration. Based on the environmental analysis of a natural gas-fired facility in the Ford City area conducted during Phase I, it was determined that such a facility would pose no major environmental problems. Therefore, this report will focus primarily on the environmental concerns associated with the operation of a refuse-fired cogeneration facility, including air pollution emissions, applicable regulations and other site specific concerns.

Air Quality Regulations

Under the Clean Air Act of 1970, the U.S. Environmental Protection Agency developed national air quality standards and established technology requirements for new sources of air pollution. The National Ambient Air Quality Standards (NAAQS) were formulated for six pollutants, including total suspended particulates (TSP), sulfur dioxide (SO₂), nitrogen oxide (NO_x), carbon monoxide (CO), photochemical oxidants and lead. Pursuant to the Act, the Illinois EPA was assigned the responsibility of developing and administering programs to meet the NAAQS.

A cogeneration facility is considered a fuel combustion source under current environmental regulations. If the system burns waste but does not process the waste for conversion to a fuel, the facility is considered to be an incinerator. The criteria pollutants associated with burning fossil fuels are TSP, SO₂, NO_x, CO and organic material, a precursor to the formation of photochemical oxidants. Pollutants released from municipal solid waste vary according to the heat, ash, sulfur and plastic content of the fuel, although the combustion of refuse generally produces emissions of TSP, SO₂, NO_x, CO and organic material.

The Clean Air Act provides for a number of regulations which are applicable to cogeneration facilities. The principal factors which determine the applicability of these regulations include the size and type of the cogeneration equipment, air pollutant emissions released by the facility and existing air quality of the area where the facility is to be developed. In Illinois, the regulations which apply to air pollution equipment are contained

in the Illinois Pollution Control Board Rules and Regulations and are enforced by the Illinois EPA.⁹ The federal New Source Performance Standards (NSPS), which apply more restrictive emission limits to certain types of new equipment, have been incorporated into these regulations. Finally, the federal Prevention of Significant Deterioration (PSD) regulations are administered under a delegation from the United States EPA.

To apply the air quality regulations to a cogeneration facility, the Illinois EPA would:

1. Examine the proposed facility to determine whether it will comply with applicable emission standards,
2. Examine the NAAQS attainment status of the site for all the regulated pollutants that would be emitted from the proposed cogeneration facility,
3. Based on the attainment status and expected emission rates of the cogeneration facility, determine whether it would be considered a major new source or a major modification to an existing major source of pollution, and whether it would be subject to either the PSD rules or nonattainment rules, and
4. Examine compliance with PSD or the nonattainment rules, as applicable.

The initial level of regulation, the emission standards, are independent of the NAAQS attainment status of the area where the emission source is to be located. The subsequent regulations depend on the NAAQS attainment status. The Illinois EPA maintains a listing of individual areas, generally defined by county and township boundaries, that are designated as being in attainment and nonattainment of the NAAQS for each of the regulated pollutants. The status of ambient air quality in

Chicago varies according to the type of pollutant. Most areas in Chicago are considered to be in attainment of the NAAQS for SO_2 , NO_x and CO. Both the Stockyards and Calumet areas are designated nonattainment for total suspended particulates and photochemical oxidants (emission of organic material).

A cogeneration project would only be subject to further review and more stringent standards set forth in the attainment and nonattainment rules if it is determined to be a major new source or a major modification to an existing major source of air pollution. A major new source is defined as a project emitting 100 tons per year of a nonattainment pollutant. A project emitting attainment contaminants, however, may be considered a major new source if it has the potential to emit 100 tons or 250 tons per year depending on the type of facility. Major modifications to an existing major stationary source refers to physical and/or operational changes that would result in an increase of any regulated pollutant beyond the emission limits set forth in the regulations.

Once a facility is determined to be a major source of pollution for any contaminant, it is subject to PSD rules for all significant net increases in attainment pollutants. Significant increases are defined in terms of the following emission rates:

1. 25 tons per year for total suspended particulates (TSP),
2. 40 tons per year for sulfur dioxide (SO_2) and nitrogen oxide (NO_x), organic material, and
3. 100 tons per year for carbon monoxide (CO).

Emission increases are evaluated in "net terms," adding contemporaneous increases and decreases at the source. Practically speaking, this means that the applicability of the regulations to a major modification may depend to some extent on the existing activity and level of emissions at the source where the project is to be developed.

Application of Regulations to Proposed Sites

The cogeneration facilities proposed for the Stockyards and Calumet areas would each employ two modular incinerators with the capacity to burn 150 tons per day of refuse per incinerator. With the appropriate design, these incinerators would comply with all the applicable emission standards. In order to determine whether these facilities would be considered a major source for any of the regulated pollutants, potential emission rates for the incinerators were calculated by environmental engineers in the Chicago Department of Consumer Services. The emission estimates for criteria pollutants are provided in Table 1. The emission factors and values used in the calculations are explained in Appendix 3.1

Based on these estimates, SO_2 is the only criteria pollutant which the incinerators would emit in excess of 100 tons per year. No other attainment pollutants would be emitted in significant amounts. Thus, the proposed cogeneration facilities would be considered a new major source of pollution for SO_2 and would therefore be subject to PSD rules for this pollutant. The PSD requirements include:

Table 1

Emission Estimates for Two 150 TPD Basic Incinerators

<u>Pollutant</u>	<u>Uncontrolled</u>	<u>Controlled</u>
TSP	66 Tons/Yr.	24.8 Tons/Yr.
SO ₂	168 Tons/Yr.	
CO	4.54 Tons/Yr.	
NOx	17.0 Tons/Yr.	

Source: City of Chicago Department of Consumer Services and
Basic Environmental Engineering Company, November 1983.

1. Application of the Best Available Control Technology (BACT) for SO_2 ,
2. Performance of an air quality analysis to show that the source will not violate the NAAQS or the PSD concentration increments (includes collection of preconstruction ambient air quality data),
3. Performance of a source impact analysis on soil, vegetation and visibility,
4. Demonstration that the source will not significantly impact Class I areas and
5. Demonstration that the source will not significantly impact designated nonattainment areas.

The proposed refuse-fired cogeneration facilities would be subject to PSD rules for SO_2 . However, since gas desulfurization, which is commonly used in utility powerplants, has not been demonstrated to be an available technology for incinerators, it is highly unlikely that an incineration/cogeneration project would require SO_2 controls. A project sponsor would be required to perform a BACT analysis, as well as an analysis of the existing air quality and projected impacts of the proposed facility. These analyses are largely procedural, and although they may require additional time in scheduling the project's development, the proposed refuse-fired cogeneration facilities under consideration should have no difficulty in fulfilling the PSD requirements and in obtaining a permit for construction.¹⁰

Wastewater and Solid Waste

Additional environmental factors to be considered in the development of a refuse-fired cogeneration facility include the generation of wastewater and solid waste by the plant. Wastewater is the product of boiler water blowdown, water treatment and water used to clean plant equipment or to wash down the ash residue from combustion. Another potential source of wastewater is run-off from material storage. Solid Waste resulting from the burning of refuse is generally in the form of fly ash and/or bottom ash.

With respect to the cogeneration facilities under consideration, the wastewater produced by the Basic incinerators would be partially evaporated within the combustion system and the balance would be combined with the ash residue. Solid waste residue could be disposed in a manner similar to that used by the City of Chicago's Northwest Waste-to-Energy Facility, where the ash residue is transferred from the plant to a common collection bin and disposed into a sanitary landfill.

Regulations for wastewater control are set forth in Chapter 17 of the Chicago Building Code, and levels of maximum concentrations of waste are determined by the Metropolitan Sanitary District of Greater Chicago. As part of the City's building permit process, the plans for waste discharge are reviewed for approval prior to construction.

Since the waste residue from the Northwest Incinerator is not considered to be a special or hazardous waste according to the Illinois EPA, it can be assumed that similar waste residue

generated by the proposed cogeneration facilities would pose no significant problems for the project sponsors. Therefore, the Resource Conservation and Recovery Act which governs the disposal of hazardous wastes would not be applied to the proposed facilities.

Other Environmental Considerations

The development of cogeneration facilities in Chicago may affect the land use and social environment of communities in which they are located. Land use and social concerns may result from an actual physical cause, such as an increase in garbage trucks transporting refuse through a neighborhood, or from the negative perception of a facility by the local residents, such as the fear that refuse-fired cogeneration will release harmful air pollutants within the community.

For the proposed cogeneration facilities, the most significant concern is related to the transportation of refuse to and from the facilities. In the Stockyards area, the proposed location for the cogeneration facility is on the site of the retired Southwest Incinerator. The area surrounding the incinerator site includes the Stockyards Industrial Area, which is bounded by Pershing Road on the north, 47th Street on the south, Halsted Street on the east and Ashland Avenue on the west. The area includes a mix of large and medium size manufacturing, wholesale trade and warehousing facilities, along with some undeveloped tracts of land. The closest residential community to the incinerator site is west of Ashland Avenue. The closed incinerator is presently being used as a municipal refuse

transfer station, which means there is an existing flow of trucks transporting refuse to and from the site.

The site proposed for the refuse-fired cogeneration facility in the Calumet area is located on the west side of the Calumet River, between 111th Street on the north and 114th Street on south. The site is bounded by 103rd Street on the north, 125th Street on the south, Avenue O on the east and Torrence Avenue on the west. This area includes several large steel producers, grain elevators, shipyards and other smaller industries. Residential communities in the Calumet area are separated from one another by tracts of undeveloped land and industrial land, and there are no residential areas adjacent to the proposed site.

The land use surrounding both the Stockyards and Calumet cogeneration development sites is primarily industrial. Thus, the installation of refuse-fired cogeneration facilities should pose no traffic-related problems for the nearby residential communities in these areas. As a further precaution, the haul routes for refuse trucks could be restricted to major arterial and collector streets which run through primarily non-residential neighborhoods.

There is, however, a perceived environmental concern by the Calumet residents which may hinder the development of a refuse-fired facility in this area. The southeastern section of Chicago has the largest concentration of waste handling facilities in the city. These facilities include municipal, special and hazardous waste landfills, liquid waste incinerators and waste treatment and storage sites. Residents of this area have expressed concern

related to possible health hazards and a potential decline in property values resulting from this concentration of waste handling facilities in their community. Residents are particularly worried about the hazardous wastes being disposed and incinerated near their homes.

Although Chicago's municipal waste is not classified as a special or hazardous waste according to the Illinois EPA, any type of waste handling, including refuse-fired cogeneration, may be viewed as an environmental threat by the residents in this area. At the same time, available land for refuse disposal is decreasing and the City needs to explore alternative technologies such as cogeneration for the handling of municipal waste. To develop such a facility in southeast Chicago, however, would require special consideration and communication with the residents to assure them that the facility would not have a negative environmental effect on their community.

IV. ALTERNATIVE OWNERSHIP and FINANCING OPTIONS

Overview

The economic viability of a cogeneration project may be dependent upon the particular ownership and financing structures adopted by the project sponsors or participants. Generally speaking, "project participants" would include all investors in the project and all parties who commit, on a long-term basis, to purchase the energy output from the facility. Such participants might include the following:

- . In the case of a refuse-fired facility, a municipality seeking alternative solutions to its waste disposal problems;
- . Industrial companies looking to the project to meet their process steam and/or electric load requirements;
- . Full-service contractors who may be energy equipment vendors with the ability to design, construct and operate a cogeneration facility; and
- . Passive investors seeking returns on their investments in the project, such as financial institutions or members of the general public.

Public entities could also play a role by guaranteeing all or a portion of the financing of the project. Public support may take the form of loans, grants or the issuance of tax exempt revenue bonds. The local electric utility company might also be interested in the project as an additional source of power or as an investment in an area outside its regulated activities. The utility may also be motivated by a desire to maintain a role in supplying some baseload and/or backup energy requirements to its industrial customers.

This section will briefly discuss the advantages and disadvantages of public vs. private ownership of an energy facility and alternative financing options which can be utilized by these owners. Since two of the Phase II feasibility studies propose the development of refuse-fired cogeneration facilities (Stockyards and Calumet), with financing provided under an industrial development bond/lease structure, particular attention is given to financing structures which utilize private equity, publicly-financed debt and tax benefits. This discussion will focus primarily on refuse-fired or "waste-to-energy" facilities, but the methods can be generalized to apply to other types of cogeneration technologies as well.¹¹

Public Ownership

Since the disposal of municipal waste is usually considered to be a public service, waste-to-energy projects are generally viewed as public works projects. However, public involvement in these types of projects can take a variety of forms. A municipality may act as a project sponsor and assume responsibility for developing the project. Also, where public funding or publicly-raised debt is to be used to finance the project, the local government may become the financing vehicle for the project. In addition, municipalities usually agree to supply some or all of the waste necessary for the operation of the facility and may assume the role of owner and/or user of the facility. However, publicly-owned projects can also involve other participants in the development and operation of the facility.

A sponsoring municipality desiring to be the owner of an energy facility, but unable or unwilling to undertake the design, construction and/or operation of the facility, could contract these functions out to one or more private parties. These could include an architectural/engineering firm and a separate construction contractor. Another option might involve a full-service contractor who assumes an obligation directly to the municipality for the cost and performance of the facility over a period of time, usually coincident with the terms of financing. Given the capital-intensive nature and technical sophistication of these projects, municipalities must consider the allocation of cost and performance risks in order to protect the public's investment. Since the full-service contractor approach allocates these responsibilities to only one party, it is generally considered to be the preferable choice of public entities.

There are two primary advantages to public ownership of a waste-to-energy facility. The first is the availability of an exemption from taxes during the operation of the facility which can be translated into lower operating costs for the municipality. Second, public ownership allows the municipality greater control over the facility and flexibility in meeting energy and waste disposal service needs.

Financing Options

Traditional sources of capital for public works projects include revenue and general obligation bonds, bank loans and current revenues. However, due to the particular nature of energy facilities, alternatives other than revenue bonds are viewed as less attractive options for these projects. For example, bank loans are generally not considered to be an option because of the large amounts of capital required for these projects. In addition, the typical duration of bank notes (less than five years) is an insufficient period of time in which to retire the debt usually associated with these projects. Similarly, current revenues would probably be insufficient since prudent fiscal management generally argues against devoting to a single project the substantial amount of resources necessary for the construction of a large-scale energy facility. Finally, general obligation (GO) bonds are in many cases not a viable means of financing the total cost of a large-scale energy facility because of restrictions on the amount of GO bonds which may be issued and the difficulty that may be involved in securing public approval for the issuance of such bonds.

Revenue Bond Financing

Where public ownership is desired, the use of revenue bonds appears to be an attractive financing mechanism. Revenue bonds are paid for by the users of the project being financed and therefore are not affected by statutory limits on debt ceilings and do not burden the credit capacity of the public entity. In the case of a refuse-fired cogeneration facility, proceeds of a

revenue bond issue could be used for the construction and start-up of the facility. Income derived from its operations, including energy revenues and tipping fees for the disposal of waste, would be used to pay for operating and maintaining the facility and to pay for the interest on and retirement of the bonds. See Appendix 4.1 for a detailed description of a revenue bond financing structure.

Tax Considerations

Since municipalities do not pay taxes, many of the tax benefits associated with private ownership of a waste-to-energy facility, such as the investment tax credit, are not available to publicly owned facilities. However, tax benefits can be made available to privately owned but publicly financed projects through the use of service contracts as discussed in the following section.

Private Ownership

Possible private owners of a refuse-fired cogeneration facility include third-party investors, system vendors or companies involved in the waste disposal or energy production business. The private owner can also be a full-service contractor with the capability to design, construct, own, operate and maintain the facility. Even if a facility is privately owned, the municipality could play a key role in issuing tax-exempt debt, such as industrial development bonds, to be used in financing the project or by supplying solid waste to the facility.

To a municipality, the principal attractions of private participation in an energy project are the reduction in project risks and certain cost advantages. These cost advantages include tax benefits which can be translated into reduced disposal costs to the public. Moreover, since the tax benefits might attract private equity participation in the project, the amount of debt financing could also be reduced.

The primary disadvantage associated with private ownership and operation of an energy facility could be the municipality's loss of control over the facility and, in the case of a waste-to-energy facility, the loss of control over its waste disposal services. To minimize the adverse effects resulting from private ownership, a municipality may enter into service contracts designed to allow a private entity to retain the tax benefits of ownership while providing the municipality with some degree of control over its waste disposal services.

Financing Options

Financing structures which utilize private equity and publicly-financed debt could be an effective way to reduce the overall cost associated with the development of a cogeneration facility. This reduction in cost is due, in part, to the fact that the federal government provides a subsidy for these facilities through tax laws. In addition to the use of tax-exempt debt, private owners of the project may be able to take advantage of certain tax benefits, including:

- . Rapid depreciation deductions or accelerated cost recovery,
- . The regular 20 percent investment tax credit and
- . A 10 percent energy tax credit on that portion of the cost of a facility which is financed with private equity or taxable debt.

The tax benefits associated with private ownership of a cogeneration facility are enhanced by the availability of tax-exempt financing. This situation is unlike that of most other privately owned facilities, where the tax benefits are partially offset by the private owner's need to use taxable debt. In addition, the availability of both tax-exempt financing and tax benefits can contribute to a reduction in the public's waste disposal costs. For example, each one percentage point of reduction in the interest rate caused by using tax-exempt debt instead of taxable debt, results in a reduction in the disposal fee by as much as \$3 to \$6 per ton of waste.¹² Also, the contribution of equity, which is at least partially recovered by claiming tax benefits, lowers the amount of debt needed to finance the project which, in turn, may lower the amount of revenues needed to service the debt.

From the onset, it must be noted that tax considerations will only be relevant and attractive to a private entity considering an ownership role in a waste-to-energy project if

that entity has sufficient taxable income to utilize the tax benefits associated with the project or if the available tax benefits can be transferred to another entity. If this first requirement is met, perhaps the most significant remaining obstacle is the so-called "governmental use" restriction.

Government Use Restriction

Because of restrictions on the availability of investment tax credits for facilities which are essentially devoted to a "governmental use" or "public function," precautions must be taken to structure this financing arrangement in a manner that will not be interpreted by the Internal Revenue Service as violating the "governmental use" rule of the Internal Revenue Code. If the facility is deemed by the IRS to constitute a public use, the private entity could lose the tax advantages associated with a private equity participation, and the public entity could be required to indemnify the private party for the loss of its tax benefits. This loss, or the threat thereof, could substantially delay the project through either litigation or administrative proceedings and could result in increased costs.

Advice of tax counsel should be sought with respect to whether a particular financing arrangement is likely to satisfy the IRS. Although the IRS has not developed any single test to determine whether a waste-to-energy facility is "used by" the public entity, two methods appear to offer a means of distinguishing these arrangements from a prohibited use:

1. Demonstrating an arms-length dealing in the creation of the arrangement, which may be required by some local jurisdictions with a competitive bidding requirement for such projects; or
2. Holding the facility open to serve the needs of a variety of public entities or commercial refuse haulers.

In addition, a municipality's particular interest in a project could present a barrier to the private entity's tax benefits. For example, the municipality may want to structure the business arrangement to generate a revenue stream from the facility. Similarly, the municipality may want to include a contractual provision limiting the "excess profits" that a private entity can realize from its ownership of the facility. In either of these cases, the arrangement must not classify any share of revenues to be received by the public entity as part of the "profits" of the facility, because such a classification might cause the IRS to view the facility as a governmental use. To avoid this problem, any revenue-sharing scheme should be characterized as a fee structure, in which the public entity shares in the income for the project before costs or profits are taken into account.

Industrial Development Bonds

The use of industrial development bonds (IDBs), which are tax-exempt bonds issued by states and municipalities but used by private businesses, is the most viable financing alternative for a privately-owned facility. Both of the financing structures described below, tax leasing and full-service contractor ownership, anticipate that the private project owners will be able to claim available tax benefits and also to use IDBs.

Where IDBs are used to finance all or a portion of a waste-to-energy facility, specific requirements for using funds generated by the bond issue are generally established by state law. These requirements, in turn, will affect the way a private ownership arrangement is structured. In order to make participation in the project attractive to a private entity, a method would have to be devised to insure that the tax benefits are transferred to the private party.

Tax-Oriented Leasing of the Facility by a Third-Party Investor/Owner

Tax leasing is a mechanism by which private equity can be used to construct a waste-to-energy facility. This arrangement is advantageous to a municipality and to a participating full-service contractor because it offers the prospect of reducing debt service payments by developing a new source of equity for the project. Under this arrangement, a third-party investor would own the facility and lease it to a contractor who is not interested in, or cannot use, the available tax benefits. The terms of the lease would generally provide that the lessee becomes solely responsible for almost all of the ongoing expenses incurred in the operation and maintenance of the facility. These expenses include obligations for insurance, repairs, maintenance, service and property taxes. Moreover, the lessee would usually have an unconditional obligation to pay, in fixed rentals, amounts sufficient to service the debt and to produce a nominal cash flow to the owner/lessor.

One advantage of a lease arrangement is that the lease payments used to retire the debt might be lower than the debt service paid on the facility under a different financing method, particularly one which envisions total financing through public ownership and revenue bond financing. This is so because the lessor does not look to the cash flow of the project to recoup his investment but rather looks to the investment achieved by claiming the tax benefits.

From the lessor's standpoint, the available tax benefits would provide an adequate rate of return for some level of investment. Therefore, the amount of equity provided by the third-party investor to the project will be determined by the value placed upon the tax benefits. The equity contributed by the third-party investor provides the same financing advantage to a waste-to-energy project as does any other equity, since funds are replaced which might otherwise have been borrowed, and thus the overall amount of debt incurred is lowered. In addition, under a leasing arrangement in which the lessor looks primarily to the tax benefits of the project, the lease payments, which are the sole source of cash flow available to the third-party investor, need be only slightly higher than what is necessary to pay debt service on any funds borrowed by the lessor. This is so because Internal Revenue Service guidelines provide that the lessor receive a nominal profit from the lease transaction in order to ensure that the tax benefits will be available to the lessor.

The business structure of a third-party tax leasing arrangement is similar to a project in which the public owns the facility. This is so because the third-party investor will want to assume the position of a secured lender rather than an equity investor who is subject to greater risks. Thus, the security arrangements and allocation of risks in this financing structure will be similar to a public ownership structure rather than to a private ownership structure.

The third-party investor lease arrangement could be used if a municipality wants to construct a waste-to-energy facility and at the same time, ensure that costs to the public are held at a minimum. To meet these objectives, the municipality must be willing to give up some control over the facility to private ownership. This would enable the project to take advantage of the available tax benefits. Furthermore, to avoid dealing with multiple parties, the municipality would also want to establish a contract with a full-service contractor and thereby gain system performance guarantees, possible fixed price contracts and completion and other guarantees. The full-service contractor, however, might be unable to use the tax benefits available and/or would not desire to invest in the construction of the project. On the whole, a third-party investor would provide the equity and obtain ownership of the facility for tax purposes, while the public entity would obtain the benefits of a full-service contractor and the contribution of private equity.

This arrangement could be implemented as described in the following scenario. On behalf of a private entity, a municipality with the authority to issue IDBs for solid waste disposal would issue bonds for a portion of the cost of the waste-to-energy facility. A third-party leasing entity would then provide a direct equity investment for the remainder of the cost of the facility. This investment would usually range between 20 and 40 percent of the total cost of the facility, depending upon the value accorded the tax benefits by the investor. These equity funds, along with the bond proceeds, would then be used to finance construction of the facility. The third-party investor would become the beneficial owner of the facility for tax purposes in the same way as a full-service contractor who contributes equity.

The bond proceeds would be loaned to the third-party investor/lessor, who would then lease the facility, under a true lease, to a private entity (full-service contractor) who would operate the facility for the disposal of waste and production of energy. To ensure that the tax benefits would not be forfeited since a public entity is involved, the lessee in this structure could not be the municipality. The lessor would, in turn, "pass through" the lease payment to the public entity. In other words, the lease payments made to the third-party investor would be "repaid" to the municipality that issued the bonds. See Appendix 4.2 for a detailed description of a tax lease financing structure.

Summary

It is difficult to make generalizations about the financing structures available for waste-to-energy or other types of cogeneration projects. This report has summarized two alternatives to 100 percent equity financing, revenue bond financing and tax leasing with the use of IDBs, in order to illustrate many of the opportunities and issues that should be considered by decision makers in their analysis of the feasibility of these projects. The effects of these alternative financing structures will be demonstrated in the following discussion of the feasibility case studies conducted for the Stockyards, Calumet and Ford City areas.

V. FEASIBILITY CASE STUDIES

Scope of Case Studies

The primary objective of Phase II of the UIICSA is the determination of the technical and economic feasibility of the three most promising sites for cogeneration development in Chicago. The Stockyards, Calumet and Ford City sites were selected on the basis of a preliminary determination of technical feasibility and the interest and cooperation of the local industrial, commercial and institutional facilities in these areas. During the course of the case studies, project staff and consultants met with managers and plant engineers of these facilities in order to collect detailed information describing the type and levels of energy consumption at the sites. Other information describing the physical layout of the sites was also analyzed in order to determine the best locations for the central facilities and the optimum steam distribution systems to serve the various energy users. Alternative fuels and technologies were analyzed and an economic analysis was performed for each site to identify the most attractive alternative. The intent of the case studies is to provide sufficient detail to form the basis for subsequent system designs which could result in the installation of one or more of these facilities in Chicago.

The primary goal of the UIICSA is to identify viable cogeneration projects and to bring these potential developments as close as possible to implementation, either by the City of Chicago as part of its waste management strategy or by private entities interested in conserving energy at their plants or those seeking investment opportunities by supplying low cost energy to industrial, commercial and/or institutional facilities in Chicago. These central cogeneration facilities could serve as part of the City's effort to both attract and retain industry within Chicago by providing the incentive of energy cost savings to firms desiring to interconnect with these systems.

The sites selected for Phase II studies represent diverse geographical areas in Chicago and are proposed to employ a range of technologies, including a refuse-burning incinerator for the Stockyards, a modified reheat incinerator for the Calumet area and a gas-turbine generator set for the Ford City industrial/commercial center. In addition, the Stockyards and Calumet studies analyze the effects of alternative financing, and the Ford City study demonstrates the effects of escalating electricity and natural gas prices over the next decade. Together, these studies provide a useful basis for defining the various conditions under which cogeneration development can be possible in Chicago.

Stockyards

During Phase I of the cogeneration project, it was determined that the Stockyards area is potentially attractive for a small refuse-fired central cogeneration steam supply.¹³ Feasibility was conditional upon the identification of a sufficient steam load among existing or new users. Based on the existing potential and the desire of the City to promote industrial development in the area, a concentrated effort was made to identify and survey industries that would be interested in connecting to a central cogeneration system. As a result of this effort, four industrial firms were found to satisfy the project requirements; these included Darling, Delaware and Company, Griffith Laboratories USA. Inc., White-Stokes Company and the Sweetheart Cup Company. In addition, two parcels of vacant land were identified for the possible location of new industry which may be attracted to the area by the incentive of discounted energy costs.

Site Considerations

The site of the proposed incinerator and cogeneration plant is shown in Figure 6. The facility may be located at the existing transfer station (formerly the Southwest Incinerator) or at any point along the distribution system. Two parcels of vacant land are available if necessary. In the following analysis, no allowance is made for the cost of land; instead, it is assumed that the City would make available a portion of its transfer station or that one of the industries would contribute the necessary space on a nominal lease basis.

D Darling	SA Sweetheart, Ashland
G Griffith	W White Stokes
I Incinerator	V1 Vacant
	V2 Vacant

Revised Distribution System for Stockyards Area.

Figure 6

When the firms in the area were surveyed for steam and electrical usage, it became evident that Darling, Delaware and Company was the only major steam user interested in the proposal. However, the other smaller firms help to levelize the load and justify the piping system which can be utilized as the basis for future expansion.

The site is presumed to have adequate refuse storage space in order to continue refuse burning during periods of non-collection, evenings and weekends. In addition, the facility is anticipated to be available for refuse processing with or without steam production 81 percent of the time. A substantial part of the advantage of the present site is its proximity to the "centroid" of available refuse. Thus, the facility should contribute positively to the City's overall collection strategy. A larger facility could lead to reduced loading of the Northwest Incinerator during winter months. Alternatively, refuse not presently collected by the City could be tipped at the site. The present small facility is believed to be conservative and should not lead to any adverse impact on collection.

System Design

It is proposed to construct a 300 tons per day (TPD) incinerator that would operate continuously to the extent of available capacity. An average steam output of 41,400 lb/hr would meet 56 percent of the steam requirements of the above industries based on their 1982 utilization. The average electrical output of 1.2 MW of electricity can readily be used by these companies or can be sold to Commonwealth Edison Company

under the Public Utility Regulatory Policies Act of 1978. If these or other companies are able to displace purchases from the local utility, a greater economic incentive exists. However, the project appears viable on either basis.

The above-sized plant was chosen in order to maximize the economic advantage as reflected by the savings in energy cogenerated as compared with conventional generation. This criterion dictates near full utilization of available steam capacity which, in the present case, is about 98 percent. While a larger plant benefits from economy of scale, it would be used less during off-peak demand and therefore cannot as effectively amortize its capital costs in terms of a low fixed charge to energy produced. Rather, additional modules can be added in order to increase capacity should further steam demand be needed due to the location of new industries or the expansion of present ones.

The proposed system would employ two 150-TPD refuse incineration boilers generating 625psig/725°F steam suitable for expansion at 150 psig (Table 2). The particular system analyzed is available from Basic Engineering Company, Inc. of Glen Ellyn, Illinois. It utilizes an efficient water-wall construction with an articulating grate suitable for mass burning of municipal refuse with minimal preprocessing. Gas cleanup equipment to be supplied with the unit is anticipated to meet environmental requirements.

Table 2

Thermal Performance of Two Refuse-Burning Modular
Incinerators for Cogeneration.

Boiler psig/ ^o F	Fired 625/725
Fuel	Refuse
Prime Mover	Steam Turbine
Capacity (1)	
Refuse, TPD	300
MMBtu/hr (HHV)	110
Steam, lbm/hr	52,400
Electric, MW(e)	1.50
Availability (2)	
Refuse, Steam (3)	0.81
Electric (4)	0.78
Available Capacity	
Refuse, TPD	243
Steam, lbm/hr	42,444
Electric, MW(e)	1.17
Available Capacity Factor (5)	
Steam	0.975
Capacity Factor (6)	
Steam (7)	0.79
Electric (8)	0.78
Refuse (9)	0.81
Average Performance	
Steam, lbm/hr	41,396
Electricity, MW(e)	
Generated (10)	1.17
Fuel, MMBtu/hr (HHV)	
Refuse Consumed	89.10
Fuel Displaced (11)	53.77
Net	35.33
IHR, Btu (HHV)/kWh(e)	30,200

(1) Based on Mazza (1981) except for refuse plants (Mastanaiah, Chaudhary and Porter, April 1982).

(2) (Available capacity)/Installed capacity).

(3) Based on planned and forced outages of 5 weeks/yr each.

(4) Based on part-load performance at steam available capacity (Mazza, 1981) and on 96% turbogenerator availability.

Economic Analysis

The Stockyards analysis was based on a nominal economic life cycle commencing in 1986 and lasting for 20 years. Experience with incinerators using municipal refuse suggests that longer life cycles are unrealistic. Financing was assumed to involve a 60 percent industrial development bond (IDB) issue and a 40 percent leveraged lease, the lease being 80 percent debt financed with a conventional loan. It is believed that this financial arrangement would be attractive to third party investors (i.e. parties other than steam users and the electric utility) because of the internal rate of return on equity investment provided.

The general economic parameters utilized in the Stockyards analysis are given in Table 3. The capital costs and value of steam, electricity and refuse processing are given in Table 4. Revenues for the plant would include a tipping fee for refuse processing and income from steam sales. Electricity is best utilized to displace purchases of the user from the local utility but can also be sold to the local utility.

Under the proposed 40 percent leveraged lease and 60 percent Industrial Development Bond financing arrangement, a discount can be given to energy users as an incentive to connect to the system and to stimulate economic development in the area. As shown in Table 5, in the case where both steam and electricity are sold to local users, the lessee can pass on a 59 percent discount in the form of reduced steam and electricity rates for cogenerated power. Or if desired, only steam can be discounted by 75 percent

Table 3

Summary of General Economic Parameters (1983 \$ and 1986 Startup).

Cost of Displaced Fuel, \$/MMBtu (1)	
Natural Gas (2)	5.27
Value of Electricity, \$/kWh(e) (1)	
Displaced (3)	0.0747
Sold (4)	0.0359
Refuse Credit (Net), \$/MMBtu (5)	0.398
Real Escalation Rates, %	
Fuel	
Natural Gas (2)	3.0
Refuse Credit	0
Electricity (3)	-0.1
O&M, Etc.	0
General Inflation Rate, %	6.5
Life, Yrs	
Life Cycle	20
Depreciation	
IDB Financed	8 (SL)
Other	5 (ACRS)
Finance	
Lease	5
Lease Loan	5
Other Loan	20
	95
Depreciation Basis, %	
Investment Tax Credit, %	10

(1) Based on Faddis (1983).

(2) Based on Class 3 Service ($>22 \times 10^6$ Btuh).

(3) Based on Industrial Rate 6L (<10 MW(e) demand).

(4) Based on Rider 4 (Utility Buyback).

(5) Based on net credit of \$3.50/ton and 4400 Btu(HHV)/lbm/(refuse).
Allows for O&M, etc.

Table 4

Economic Performance of Two Refuse-Burning Modular Incinerators
for Cogeneration Operated at Full Available Capacity Without
Credit for Conventional Equipment (1983 \$ and 1986 Startup).

	Use of Electricity Generated	
	Sales to Utility	Displaced Purchases
Capital Cost \$1000		
Direct Cost		
Plant (1)	12,310	12,120
Credit	0	0
Net Direct Cost	12,310	12,120
Indirect Cost (2)	4,310	4,240
Distribution Cost (3)	2,990	3,770
Total Cost	19,610	20,130
1st Yr Cash Flows, \$1000		
Incomes are Positive		
Fuel		
Consumed	-	-
Displaced (4)	2,484	2,484
Net	2,484	2,484
Refuse Credit, O&M	315	315
Electricity		
Displaced (5)	0	766
Sold	368	0
Total	368	766
Net Savings (6)	3,167	3,565
Simple Payback, Yrs	6.2	5.6

(1) Based on Chaudhary and Porter (December 1982), adjusted for 1983 \$.

(2) Based on 35% of direct cost.

(3) Based on 207 \$/ft for 12,550 ft of equally split 12-in main and 6-in condensate return with sales to utility. Without sales to utility, add 54 \$/ft for electrical cables. Add 15% indirect costs.

(4) Based on conventional equipment being fired with natural gas (Class 3).

(5) Based on Industrial Rate 6L (<10 MW(e) demand).

(6) Excludes capital charges and taxes.

and electricity charged at the utility rate. Should the electricity be sold to the utility, the steam discount reduces to 62 percent. These reduced rates are the stimulus to economic development provided by the project.

In terms of 100 percent equity investment, real rates of return are for displaced electrical purchases and sales to the utility. With the assumed 6.5 percent general inflation rate, the effective rates of return are correspondingly 22 percent and 21 percent. Unfortunately, these rates fall short of the values most firms would require (i.e. about 10 percent in constant dollars or 26 percent in current year-of-service dollars). Thus, the use of lease and/or debt financing is important to the viability of the project. The project becomes economically feasible because only 8 percent of the capital is equity financed, 60 percent of the capital is IDB financed at 5 percent above general inflation or at 12 percent in current year-of-service dollars, and 32 percent of the capital is financed at 11 percent above general inflation or at 18 percent in current year-of-service dollars.

Table 5

Effect of Financing for the Two Refuse-Burning Modular Incinerators for Cogeneration With and Without Sales to Utility, 1983 \$ and 1986 Startup (1).

	Use of Electricity Generated			
	Sales to Utility		Displaced Purchases	
	100% Equity	60% Debt (2) 40% Lease (3)	100% Equity	60% Debt (2) 40% Lease (3)
Loan Rate	-	5.0	-	5.0
Lease Loan Rate	-	10.0	-	10.0
Equity	100	-	100	-
ROI, %	13.9	-	14.9	-
Discount Rate, %	-	18.0	-	18.0
Allowable Discounts, %				
Based on Steam Only	-	62.3	-	74.7
Based on Steam and Electricity	-	-	-	58.8

(1) Loan, ROI and discount rates are relative to general inflation of 6.5%.

(2) IDB financing for taxable owner.

(3) Lessor ROI = 18% on 20% equity with debt financed at 11%. Lease and loan payments are levelized in current (year-of-service) dollars over 5 years.

Calumet

In addition to the Stockyards, the results of Phase I of the UIICSA project led to the identification of the Calumet area as a potentially attractive site for refuse-fired cogeneration. This area was also identified as a possible incineration site by Environdyne Engineers, Inc. in a study performed for the Chicago Department of Public Works which analyzed alternatives to the use of two nearby landfill sites expected to be exhausted in the next five years. The present study resulted in the identification and surveying of three local companies which appear capable of benefitting from the proposed system: Republic Steel, Cargill, Inc. and General Mills. Republic Steel is the largest steam user, consuming monthly averages of 72,000 to 147,000 lb/hr of 300 psig/680° steam. The combined use ranges from 110,000 to 210,000 lb/hr, with the other users employing 150 psig saturated steam. Republic Steel alone can easily consume all of the several megawatts of electricity cogenerated in a steam-turbine-based cogeneration plant producing steam in the required amounts.

Site Considerations

The site of the proposed incinerator and cogeneration plant is shown in Figure 7. The facility is located across the Calumet River from Republic Steel which is near 111th Street and South Burley Avenue. The piping and electrical cables (where appropriate) are considered to span the river along an existing utility bridge. The distance from the facility to the point of connection at the existing Republic Steel power plant is about 3,300 feet.

Figure 7

Calumet Area Site for Refuse-Fired Cogeneration Plant.

Also shown in Figure 7 are additional distribution lines to General Mills and Cargill, which are on the same side of the river as the proposed facility. The additional distribution distance is about 13,390 feet. About 40 acres of land appear to be suitable for the site of the facility. In addition, the site is presumed to have enough space for refuse storage to permit continuous operation during periods of non-collection, evenings and weekends.

System Design

It is proposed to utilize multiple 150 TPD water-wall incinerators that would consume refuse continuously to the extent of available capacity, or about 81 percent of the installed capacity. The electrical output of several megawatts can be sold to the local utility under provision of PURPA. Or more advantageously, it can be used to displace purchases of a local user of electricity. However, such displacement is currently not an established practice, and so both options are analyzed here.

The proposed modular system is essentially the same as that proposed for the Stockyards area. The system, based on 150-psig saturated steam utilization, produced 26,200 lb/hr of steam and 0.75 MW of electricity. However, when the steam is expanded to 300 PSIG as required by Republic Steel, only 0.32 MW of electricity is produced. Further, the steam must be reheated in the boiler in order to satisfy the temperature requirement of 680°F, and the steam production is reduced to 24,000 lb/hr. A heat balance is summarized in Figure 8 for the modified reheat incinerator.

Figure 8
Modified Modular Refuse Incinerator and Cogeneration
Plant Designed for Republic Steel Company Steam Supply.

The Calumet analysis focused upon the determination of the optimum number of modified reheat incinerators needed to serve part or all of the Republic Steel requirement at 300 psig. Excess capacity of these units together with an optimum number of non-reheat units were separately considered to serve Cargill and General Mills at 150 psig, additionally, as an industrial district steam supply. The excess capacity of the reheat units would be dropped in pressure before distribution. The system could be expanded in the future with additional units being added of the required type, depending on present or new user needs.

Economic Analysis

As in the Stockyards case, the Calumet analysis was based on an economic life cycle commencing in 1986 and lasting for 20 years. Financing for the purpose of optimizing is considered on the basis of 100 percent equity. However, the selected system was also analyzed assuming a 60 percent IDB and a 40 percent leveraged lease. The owner is considered taxable and could be one or more of the steam users, perhaps separately incorporated, or could be a "third party". For 100 percent equity investment, results are summarized in terms of rate of Return on Investment (ROI). In the case of IDB-lease financing, results are presented in terms of maximum allowable percentage discount to users calculated with savings credited to either steam or both steam and electricity utilized.

The basic economic parameters utilized in the Calumet analysis were essentially the same as those applied in the Stockyards case (Table 3). However, in the Calumet case, two system options were considered. First, a single-user system which requires modified heat incinerators is considered for Republic Steel only. In addition, an extended system designed to serve part or all of the steam requirements of Cargill, Inc. and General Mills was also considered.

For the case of the single-steam user, the system performance factors are summarized in Table 6 for three to six modular incinerators. Capital costs and the value of steam, electricity and refuse processed during the first year of operation (1986) are given in Table 7. Based on a real interest rate (minimum acceptable return on investment) of 18 percent relative to general inflation, the case of sales of electricity to the local utility has an optimum number of five modular incinerators with rated capacities of 750 TPD of refuse, 120,000 lb/hr of 300 psig/680°F steam and 1.6 MW of electricity. This case would supply about 76 percent of the purchase-fuel steam requirements of Republic Steel.

Results for alternative financing are given in Table 8. For 100 percent equity financing, the ROIs are 19.6 and 21.0 percent, respectively, for the cases of sales of electricity to the utility and displaced purchases. The case of the 60 percent debt (IDB) and 40 percent lease is based on levelized loan and lease payments in year of service dollars. For sale of electricity to

Table 6

Thermal Parameters for Modified Reheat Incinerators
with Cogeneration for Republic Steel Steam Supply

	Number of Incinerators			
	3	4	5	6
Installed Capacities (1)				
Refuse, TPD	450	600	750	900
Steam Supply, lbm/hr	72,000	96,000	120,000	144,000
Net Electricity, MW(e)	0.95	1.26	1.58	1.89
Availability (2)				
Refuse, Steam (3)	0.81	0.81	0.81	0.81
Electric (4)	0.78	0.78	0.78	0.78
Available Capacity				
Refuse, TPD	365	486	608	729
Steam, lbm/hr	58,320	77,760	97,200	116,640
Electric, MW(e)	0.77	0.98	1.23	1.47
Available Capacity Factor (5)				
Steam	1.00	0.97	0.88	0.78
Capacity Factor (6)				
Steam (7)	0.81	0.79	0.71	0.63
Electric (8)	0.78	0.78	0.78	0.78
Refuse (9)	0.81	0.81	0.81	0.81
Average Performance				
Refuse, TPD	364	486	608	729
Steam, lbm/hr	58,300	75,350	85,600	91,050
Electricity, MW(e) (10)	0.77	0.98	1.23	1.47
Fuel, MMBtu/h				
Refuse (11)	133	178	223	267
Displaced (12)	87	112	128	136
Net	46	66	95	131

- (1) Based On Massa (1981) except for refuse plants (Mastanaiah, Chaudhary and Porter, April 1982).
- (2) (Available capacity)/(Installed capacity).
- (3) Based on planned and forced outages of 5 weeks/yr each.
- (4) Based on part-load performance at steam available capacity (Mazza, 1981) and on 96% turbogenerator availability.
- (5) (Average load)/(Available capacity).
- (6) (Average load)/(Installed capacity).
- (7) (Availability) x (Available capacity factor).
- (8) Based on cogeneration mode of operation for steam load (Mazza, 1981) with balance on powerplant mode, up to full available capacity.
- (9) Based on part-load performance (Mazza, 1981) and on operation in incineration mode up to full available capacity.
- (10) Cogeneration mode and powerplant mode.
- (11) Based on 4400 B/lbm (refuse).
- (12) Based on 1252 Btu/lbm (steam) and present boiler efficiency of 84%.

Table 7

Economic Performance of Refuse-Burning Modular Incinerators with Cogeneration for Republic Steel Without Credit for Conventional Equipment (1983 \$ and 1986 Startup).

	Sales to Utility				Use of Electricity			
	Number of Units				Displaced Purchases			
	3	4	5	6	3	4	5	6
Capital Cost \$1000								
Direct Cost								
Plant	15,370	18,920	22,140	26,020	15,100	18,560	21,690	25,490
Credit	0	0	0	0	0	0	0	0
Net Direct Cost	15,370	18,920	22,140	26,020	15,100	18,560	21,690	25,490
Indirect Cost (35%)	5,380	6,620	7,750	9,110	5,290	6,500	7,590	8,920
Distribution Cost(1)	790	790	790	790	990	990	990	990
Total Cost	21,540	26,330	30,680	35,920	21,380	26,050	30,270	35,400
1st Yr Cash Flows, \$1000								
Incomes are Positive								
Fuel Displaced (2)	4,014	5,188	5,894	6,269	4,014	5,188	5,894	6,269
Refuse Credit, O&M	467	621	777	932	467	621	777	932
Electricity								
Displaced (3)	0	0	0	0	622	825	1,035	1,238
Sold (4)	299	397	497	595	0	0	0	0
Total	299	397	497	595	622	825	1,035	1,238
Net Savings	4,780	6,206	7,168	7,796	5,103	6,634	7,706	8,439
Simple Payback, Yrs	4.51	4.24	4.28	4.61	4.19	3.93	3.93	4.19
Present Worth	700.55	1982.17	2065.32	489.25	1680.12	3325.22	3791.99	2572.77
Economic Choice								

- (1) Based on 207 \$/ft for 3300 ft of 12-inch main and 6-inch condensate return.
Add 54 \$/ft for electric cables in case of displaced purchases of electricity.
- (2) Class 3 service of natural gas.
- (3) Rate 6L.
- (4) Rider 4.

Table 8

Effect of Financing for the Five Modified Refuse-Burning Modular Incinerators with Cogeneration for Republic Steel Only, With and Without Sales to Utility, 1983 \$ and 1986 Startup.

	Use of Electricity Generated			
	Sales to Utility		Displaced Purchases	
	100% Equity	60% Debt 40% Lease	100% Equity	60% Debt 40% Lease
Loan Rate,%	-	5.0	-	5.0
Lease Loan Rate,%	-	11.0	-	11.0
Lessor ROE(20% Equity),%	-	18.0	-	18.0
ROI,%	19.61	-	20.98	-
Discount Rate,%	-	18.0	-	18.0
Allowable Discounts,%				
Based on Steam Only	-	78.27	-	86.83
Based on Steam and Electricity	-	-	-	75.23

the utility, steam can be discounted by 78 percent relative to conventional generation. For the case of displaced purchases of electricity, the discount increases to 87 percent; or both steam and electricity can be discounted by 75 percent. These savings appear to be very attractive.

Table 9 describes the various numbers of incinerators needed to provide steam to Cargill and General Mills at 150 psig, in addition to the extended distribution system previously discussed. Excess capacity of the modified reheat incinerator to be used for Republic Steel was assumed to be available. General economic parameters were taken to be the same as described for the single-user system, and the result of the incremental present-worth method for system optimization are given in Table 10. For this system, the optimum number of units is one, and the combined capacities of the reheat and non-reheat incinerators are: 900 TPD of refuse, 120,000 lb/hr of 300 psig/680°F steam, 26,200 lb/hr of 150 psig saturated steam and 2.33 MW of electricity. Approximately 55 percent of the steam requirements of Cargill and General Mills would be met, in addition to 76 percent of the needs of Republic Steel. The combined need met would be 69 percent.

Results are summarized in Table 11 for the case of equity and debt-leasing financing. For 100 percent equity financing, the ROIs are 19.5 and 20.3, respectively, for the cases of sales of electricity to the utility and displaced purchases. The case of 60 percent debt (IDB) and 40 percent lease is based on levelized loan and lease payments in year of service dollars.

For sales of electricity to the utility, steam can be discounted by 77 percent relative to conventional generation. For the case of displaced purchases of electricity, the discount increases to 84 percent; or both steam and electricity can be discounted by 74 percent. These savings also appear to be very attractive.

Table 9

Thermal Parameters for Refuse-Burning Modular Incinerators with Cogeneration
for Calumet Area Including Republic Steel, Cargill, and General Mills

	Alternative		
Number of Incinerators			
Reheat	5	5	5
Conventional	<u>1</u>	<u>2</u>	<u>3</u>
Total	6	7	8
Installed Capacities			
Refuse, TPD	900	1050	1200
Steam Supply, lbm/hr			
300 psig	120,000	120,000	120,000
150 psig	<u>26,200</u>	<u>52,400</u>	<u>78,600</u>
Total	146,200	172,400	198,600
Net Electricity, MW(e)	2.33	3.08	3.83
Availability			
Refuse, Steam	0.81	0.81	0.81
Electric	0.78	0.78	0.78
Available Capacity			
Refuse, TPD	729	851	972
Steam, lbm/hr			
300 psig	97,200	97,200	97,200
150 psig	<u>21,200</u>	<u>42,400</u>	<u>63,700</u>
Total	118,400	139,600	160,900
Electricity, MW(e)	1.82	2.40	2.99
Available Capacity Factor			
Steam	0.93	0.86	0.78
Capacity Factor			
Steam	0.75	0.70	0.63
Electric	0.78	0.78	0.78
Refuse	0.81	0.81	0.81
Average Performance			
Steam, lbm/hr			
for Republic Steel	85,600	85,600	85,600
for Cargill and			
General Mills	<u>26,900</u>	<u>34,600</u>	<u>39,480</u>
Total	112,500	120,200	125,080
Electricity, MW(e)			
Generated	1.82	2.40	2.99
Fuel, MM Btu/hr (HHV)			
Refuse Consumed	267.30	311.85	356.40
Fuel Displaced	<u>162.52</u>	<u>172.52</u>	<u>178.86</u>
	104.78	139.33	177.54

Table 10

Economic Performance of Refuse-Burning Modular Incinerators with Cogeneration for Calumet Area Operated Without Credit for Conventional Equipment (1983 \$ and 1986 Startup),

	Use of Electricity							
	Sales to Utility				Displaced Purchases			
	Number of Units ★				Number of Units ★			
	5	6	7	8	5	6	7	8
Capital Cost \$1000								
Direct Cost								
Plant	22,140	25,920	29,290	32,660	21,690	25,390	28,670	31,950
Credit	0	0	0	0	0	0	0	0
Net Direct Cost	22,140	25,920	29,290	32,660	21,690	25,390	28,670	31,950
Indirect Cost	7,750	9,070	10,250	11,430	7,590	8,890	10,040	11,180
Distribution Cost	790	3,970	3,970	3,970	990	5,010	5,010	5,010
Total Cost	30,680	38,960	43,510	48,060	30,270	39,290	43,720	48,140
1st Yr Cash Flows, \$1000								
Incomes are Positive								
Fuel Displaced	5,894	7,508	7,970	8,263	5,894	7,508	7,970	8,263
Refuse Credit, O&M	777	932	1,037	1,243	777	932	1,087	1,243
Electricity								
Displaced	0	0	0	0	1,035	1,192	1,572	1,958
Sold	497	573	755	941	0	0	0	0
Total	497	573	755	941	1,035	1,192	1,572	1,958
Net Savings	7,168	9,013	9,812	10,447	7,706	9,632	10,529	11,464
Simple Payback, Yrs	4.28	4.32	4.43	4.60	3.93	4.08	4.11	4.20
Present Worth	2,065	2,390	1,776	635	3,325	3,845	3,847	3,333
Economic Choice		*				*		

* Five units are modified reheat type for Republic Steel.

Table 11

Effect of Financing for Refuse-Burning Modular Incinerators with
Cogeneration for Calumet Area, 1983 \$ and 1986 Startup.

	Use of Electricity Generated			
	Sales to Utility		Displaced Purchases	
	100% Equity	60% Debt 40% Lease	100% Equity	60% Debt 40% Lease
Loan Rate,%	-	5.0	-	5.0
Lease Loan Rate,%	-	11.0	-	11.0
Lessor ROE(20% Equity),%	-	18.0	-	18.0
ROI,%	19.5	-	20.3	-
Discount Rate,%	-	18.0	-	18.0
Allowable Discounts,%				
Based on Steam Only	-	77.0	-	83.9
Based on Steam and Electricity	-	-	-	73.6

Ford City

The third site selected by project researchers for a Phase II technical and economic feasibility analysis was the Ford City Commercial/Industrial District on the southwest side of Chicago. This site offers a unique opportunity for the installation of a central cogeneration facility because of the mix of residential, commercial and industrial establishments in the area and an existing steam plant and distribution system within the site. In addition to facilities located within the Ford City Shopping Center and Industrial park, there are several major facilities within a two-mile radius which could be tied into an expanded central system, including Midway Airport, two chemical process plants and additional industrial, commercial and institutional facilities. For this particular study, however, only the Ford City Shopping Center and Industrial Center, located between Cicero Avenue and Pulaski Road, were considered primarily because:

1. The site is owned and operated by essentially one corporate entity thus limiting the number of separate decisions usually necessary for such a project;
2. There is apparently an adequate electrical and thermal load to justify an economically viable system; and
3. Because there are no dedicated streets and the primary business of the potential owners is not generating electricity, it appears likely that there will be no franchise infringement.

Site Considerations

The general site layout of the Ford City Shopping Center, Industrial Center and Industrial Park is shown in Figure 9. As noted above, the site appears to be particularly attractive for the installation of a central cogeneration system for several reasons. In addition to those favorable characteristics already mentioned, the site includes:

1. A unique blend of residential, commercial, light industrial and educational facilities which could use both electrical power and steam provided by a cogeneration facility;
2. The existence of a steam plant plus a piping distribution system; and
3. The availability of vacant land and unoccupied space within the Industrial Center which could attract manufacturing plants with significant steam requirements, particularly in the food processing industry.

The main structures on the site include the Industrial Center and the Shopping Center, the General Services Administration (GSA) Warehouse, Sweetheart Cup Corporation and the Richard J. Daley College. The Industrial Center and Shopping Center are connected by two one-hundred-foot-wide tunnels which originally served as utility tunnels and as passages for workers. Currently about one-half of the east tunnel is used to house retail stores located underneath the Shopping Center, parking lot and the front portion of the Industrial Center building.

The north portion of the Ford City property is zoned for motor freight facilities and is currently used as such. If the proposed central cogeneration facility were successful in

1 TOOTER ROLL INC.	7 VILLAGE APARTMENTS
2 HOLIDAY INN MOTEL	8 BANK
3 BANK	9 FORD CITY EAST SHOPPING CENTER
4 POWER PLANT	10 KATALCO CHEMICAL CO.
5 UNOCCUPIED	11 DIAMOND SHAMROCK CORP.
6 BANK AND OFFICES	12 ELECTRONICS PLANT

Fig. 9 Ford City Shopping Center and Industrial Park.

providing both low cost electricity and steam to manufacturing firms, it may be necessary to change the zoning to accommodate new process plants which could use low-cost steam. If this were done, along with the already vacant land on the site, approximately 140 acres of land could be made available for industrial development along with the unoccupied portion of the Industrial Center.

A central cogeneration facility could conceivably attract manufacturing firms, especially in the food processing industry, which have requirements for process steam. This would occur because the load already on site is for the most part electrical, thus indicating that a surplus of steam will be produced. Preliminary indications are that the match is fairly close, provided changes can be made in the end use technologies on the site. For example, the steam load could be maintained throughout the summer if the compressive chillers were replaced by similarly sized absorptive chillers throughout the site.

System Design

The electricity demand for the Ford City site is approximately 20 to 23 megawatts, and the steam demand is about 100,000 lb/hr. To serve these energy needs, it is proposed that the existing steam plant buildings and facilities be used as the site of a new cogeneration facility. The system selected for the central cogeneration system is based on a gas-turbine generator set.

The specific model selected for the feasibility study is the Mars engine produced by the Solar Turbine Division of Caterpillar

Company. This generator set, nominally rated at 7200 kW, has been used extensively in industrial power and cogeneration systems and is fairly typical of the state-of-the-art. The unit can produce about 6950 kW of power while generating 30,085 lb/hr of steam at 15 psig and 350°F. This is roughly the equivalent of one-fourth of the peak capacity required for the Ford City site for both electricity and steam. Each gas turbine consumes about 90.3 MMBTU/hr of natural gas for an electrical efficiency of about 28.6 percent. The overall efficiency of the unit, including a heat recovery efficiency of about 44.3, is about 73.8 percent. Table 12.1 shows the fuel requirements, power output and heat recovery potential for these units at full power and at 75 percent and 50 percent full-power, respectively. Table 12.2 shows the electrical and heat recovery efficiency of the plant at these power levels.

Economic Analysis

One of the problems that must be considered when performing an economic analysis of a cogeneration facility is the uncertainty attached to many of the economic assumptions. Since a primary consideration in determining the economic viability of the proposed cogeneration system is the differentiation in natural gas and electricity prices, an attempt was made in the Ford City study to predict the relationship between these price increases over the next decade. The results of this analysis show that since 1974 the cost of natural gas has increased at a rate of roughly 14 percent, while the price of electricity increased by 11 percent per year. The ratio of electricity to

Table 12.1
GAS TURBINE PERFORMANCE

Fuel Flow (MMBtu/h)	Power (kW)	Exhaust Gas		Heat Recovered* (MMBtu/h)
		Temperature (°F)	Flow (1000 lb/h)	
80.3	6950	768	304	35.6
65.3	5210	707	207	27.6
52.7	3475	680	243	23.1

*Assumes a 300°F exit temperature.

Table 12.2
GAS TURBINE SYSTEM EFFICIENCY

Power (%)	Elect. Eff. η_e (%)	Heat Recovery Eff. η_{HR} (%)	Total Eff. η_T (%)
100	29.5	44.3	73.8
75	27.2	42.2	69.4
50	22.5	43.8	66.3

natural gas prices (using \$/MMBtu) decreased from 7.52 to 6.2 during that time. However, more recent history shows increases in electricity of about 14 and 15 percent while natural gas prices increased by about 9 percent. In real terms this would correspond to about 10 percent for electricity and 4 percent for natural gas.

Future expectations of electricity prices for the Chicago area are for increases in the range of 15 percent until about 1988 when Commonwealth Edison's construction program is planned to be completed. Thereafter, electricity prices are expected to remain constant in real terms, through at least the end of the century. This scenario seems fairly certain for the period through 1988 given the financial requirements of Commonwealth Edison, but beyond that time it is much more difficult to predict. On the other hand, natural gas prices in the future are somewhat more uncertain because of regulation. Natural gas prices in Chicago and the northern portion of Illinois are relatively low compared to the rest of the Midwest and the nation because the local gas utilities have long term contracts for relatively inexpensive natural gas. However, natural gas deregulation looms on the horizon, and expectations are that prices will increase dramatically. This is the conventional wisdom despite recent deregulation of oil prices. In any event, the American Gas Association expects average natural gas prices to increase by approximately 2.5 percent per year over the period from 1982-1992 on a national basis. Allowing for Chicago's currently low price, we will assume that natural gas prices will

increase at a 4 percent clip (in real terms) per year over the next ten years and substantially level off after that time.

In performing the economic analysis for the Ford City cogeneration system, energy prices in effect in mid-1983 were used as a basis. All inflation rates were assumed to be in real terms so that all results are in 1983 dollars. Similarly, all internal rates of return were calculated in real terms and should be adjusted for inflation as needed.

Three separate cases were addressed in the analysis. The economic parameters for each case are shown in Table 13. Case B may be considered the base case, while Case A assumes that natural gas will not inflate over the life of the plant (20 years). Both Cases A and B assume that a 10 percent investment tax credit is allowed and that the entire installed plant is considered to be five-year depreciable property which, under ACRS rules, can be depreciated according to a schedule of 15, 22, 21 and 21 percent per year. Case C, on the other hand, is the same as Case B, except that there is no tax credit and depreciation takes place over 15 years using a sum-of-the-years digits (SYD) schedule. This last case would represent a more conventional economic analysis approach which indicates some of the effects of special treatment for similar investments. No energy tax credit is considered.

Table 13
ECONOMIC PARAMETERS

	Case		
	A	B	C
Avg. Electricity Cost (¢/kWh)	7.5	7.5	7.5
Avg. Natural Gas Cost (\$/MMBtu)	4.90	4.90	4.90
Avg. Steam Cost (\$/1000 lb)	8.0	8.0	8.0
Operation and Maintenance (¢/kWh)	1.0	1.0	1.0
Tax Rate (%)	48	48	48
Tax Credit (%)	10	10	10
Depreciation Schedule	ACRS	ACRS	SYD
Property Tax and Ins. (%)	0.9	0.9	0.9
Depreciable Life (Years)	5	5	15
System Life (Years)	20	20	20
Real Inflation Rates (%/yr)			
Natural Gas/Steam	0	4	4
Electricity	6	10	10
Inflation Terms (yrs)			
Natural Gas/Steam	0	10	10
Electricity	5	5	5

Table 14 shows the capital costs of two different systems using two different sets of assumptions about the capital cost of the system. Options 1 and 2 are based on installing four gas turbine-generators and all related equipment using either \$1100/kW or \$655/kW as its installation cost. The cost of \$1100/kW is from Porter¹⁴ while that of \$655/kW was based on data received from the manufacturer concerning recent installations. Options 3 and 4 are based on the idea that the same engines used in 1 and 2 have been re-rated from 7200 kW to 8800 kW at standard conditions and are installed for the same price per engine-generator set. The effect, of course, is to decrease the \$/kW cost of the equipment.

As Table 15 shows, the total installed cost of a cogeneration system at the Ford City site can range from a low of \$877/kW to a high of \$1,477/kW. Generally, this seems to bracket the capital costs normally encountered for such systems. The capital costs at the Ford City site should have a tendency to be on the low side because of the existing steam plant building and associated distribution system and the relatively compact site serving a diverse group of potential customers.

The detailed results for each of the twelve combinations of capital cost options and economic cases are given in Appendix 5.3. Table 12 shows the results of these calculations in terms of the Real Internal Rate of Return (RIRR) for each project. For the base economic parameters assumed in Case B, the RIRR ranges from a low of 19.6 percent to a high of 29.9 percent. Considering more recent inflation rates of approximately 4 to 5

Table 14

CAPITAL COST OF COGENERATION SYSTEM OPTIONS

	System Option			
	1	2	3	4
No. Gas. Turbine Gen. Sets	4	4	3	3
Elect. Output/Unit (kW)	6,950	6,950	8,530	8,533
System Capacity (kW)	27,800	27,800	25,600	25,600
Cost/kW (\$/kW)*	1,100	655	896	533
Gas Turbine-Generator Cost* (\$1,000)	30,580	18,209	22,935	13,657
Steam Dist. System (15,840 @ \$300/ft) (\$1,000)	4,752	4,752	4,752	4,752
Power Plant Rehabilitation (\$1,000)	1,000	1,000	1,000	1,000
End User Retrofit (\$1,000)	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>
SUBTOTAL (\$1,000)	37,332	24,961	29,687	20,409
CONTINGENCY (10%) (\$1,000)	<u>3,733</u>	<u>2,496</u>	<u>2,969</u>	<u>2,041</u>
TOTAL CAPITAL COST (\$1,000)	41,065	27,457	32,656	22,450
COST (\$/kW)	1,477	988	1,276	877

*Includes gas turbine, generator, waste heat boiler, controls, gas compressor and interconnection switch gear.

Table 15

REAL INTERNAL RATE OF RETURN (%) FOR FORD CITY COGENERATION SYSTEMS

Economic Case	System Option			
	1	2	3	4
A	17.5	24.4	21.0	27.5
B	19.6	26.6	22.5	29.9
C	16.1	22.7	18.9	25.8

percent, the rate of return would range from about 25 to 35.8 percent. Under the more conservative rates assumed in Case A for the four options, the RIRR range from 12.5 to 27.5 percent, which is roughly comparable to the Case B results. Finally, ignoring any tax credits and the greatly accelerated ACRS depreciation schedules does not strongly affect the returns for each option under Case C assumptions. The RIRRs range from a low of 16.1 percent to a high of 28.5 percent. These correspond to inflation adjusted internal rates of return ranging from 21.3 to 31.5 percent.

It should be kept in mind that these results ignore any leveraging effects due to debt. It is clear that if a significant amount of debt were used to finance the initial investment, the rate of return based on equity would increase substantially. These results, then, represent the minimum RIRR assuming that all of the capital cost is equity financed.

In summary, based on the capital cost and economic parameters assumed in this analysis, the real rates of return on total assets would be quite attractive for many investors. Further analysis is required to define the average selling price (or voided cost) per kWh of electricity for Ford City (assumed to be 7.5¢/kWh) and the value of steam (assumed to be \$8/1000 lb). These actual values would be dependent upon the current tenant size and mix and the technologies and fuels used to generate steam on site. This analysis does, however, indicate that a central cogeneration facility at Ford City could be an economically attractive investment if capital costs can be

limited to under \$1,500 per installed electrical kilowatt and energy price increases follow a pattern for at least the next five years similar to those of the last two years.

VI. SUMMARY AND CONCLUSIONS

Overview

During Phase II of the Urban Integrated Industrial Cogeneration Systems Analysis (UIICSA), the City of Chicago identified three potentially viable cogeneration development sites in Chicago and analyzed the technical and economic feasibility of cogeneration at these sites. The Stockyards and Calumet industrial areas and the Ford City commercial/industrial district were selected primarily on the basis of the existing energy demand of industrial firms and other energy-intensive facilities in these areas. Consideration was also given to the proximity of these firms to one another and to other facilities that could tie into a central energy facility, the potential for industrial development in these areas and the possibility of coordinating the location of a central cogeneration facility with the City of Chicago's municipal waste management strategy. In addition, the sites were assessed as to their probable compliance with local zoning, building code and environmental regulations. Finally, the UIICSA attempted to define the effects of alternative financing and future natural gas vs. electricity prices on the economic viability of cogeneration development in Chicago.

Summary of Results

The sites selected for the Phase II feasibility studies represent diverse geographical areas in Chicago and are proposed to employ a range of technologies. As the following case summaries will show, these studies provide a useful basis for defining the various conditions under which cogeneration can be a viable source of energy supplies in the City of Chicago.

Stockyards

The Stockyards area was analyzed as a case study for cogenerated energy recovery from refuse using modular water-wall mass-burning incinerators. The system would operate at near available capacity and supply about 56 percent of the steam requirements of four local industries. The facility would be rated at 300 TPD of refuse processing, 52,400 lb/hr of steam and 1.5 MW of electricity. Revenues for the plant would include a tipping fee for refuse processing and income from steam sales. Electricity would be best utilized to displace purchases but could also be sold to the local utility according to federal regulations governing cogeneration and small power production from alternative energy.

Under a proposed 40 percent leveraged lease and 60 percent industrial development bond financing structure, an energy discount could be given to the four firms interconnecting with the facility. In the case of sales of both steam and electricity to local users, a discount of up to 59 percent may be applied to these sales. With respect to a 100 percent equity investment, effective rates of return fall short of the values most firms

would require. Thus, the use of lease and/or debt financing is essential to the viability of this project.

Calumet

The Calumet area was also analyzed as a case study for cogenerated energy recovery from refuse using modular water-wall mass-burning incinerators. The facility was considered to serve either a single local company (Republic Steel) or three companies (Republic Steel, Cargill and General Mills). The situation is complicated in that Republic Steel needs an average of 113,000 lb/hr of 300 psig/680° steam which requires a modified reheat incinerator for the purpose of cogeneration. The other users employ an average of 49,000 lb/hr of 150 psig saturated-vapor steam which does not need to be reheated. However, excess steam from the higher pressure supply can be used for distribution to users at 150 psig by throttling down in pressure, which also reduces the need for additional incinerators. As in the Stockyards case, revenues for the plant would include a tipping fee for refuse processing and income from steam sales. Electricity would again be best utilized to displace purchases from the local utility.

For the case of the single steam user, the optimum system has a rated capacity of 750 TPD of refuse, 120,000 lb/hr of 300 psig/680° steam and 1.6 MW of electricity. It would supply about 76 percent of Republic Steel's steam generated from purchased fuels. Steam and electricity could be discounted about 75 percent relative to conventional costs under a 60 percent industrial development bond and 40 percent leveraged lease

financing arrangement. If 100 percent equity were utilized, the project would yield a return on investment in current dollars of 26 percent and 27 percent, respectively, for sales to the utility and displaced purchases.

For the multiple-user system, the combined rated capacities are 900 TPD of refuse, 120,000 lb/hr of 300 psig/680°F steam, 26,200 lb/hr of 150 psig saturated-vapor steam and 2.33 MW of electricity. About 69 percent of the combined steam requirements of the three users would be met. Steam and electricity could be discounted about 74 percent relative to conventional costs, by employing a similar 60 percent Industrial Development Bond and 40 percent leveraged lease financing plan. If 100 percent equity financing were utilized, the return on investment in current dollars would again be 26 percent and 27 percent, respectively, for electricity sales to the utility and displaced purchases. Thus, the project would be economically viable under both financing arrangements.

Ford City

The Ford City commercial/industrial district was analyzed as to the feasibility of installing a central cogeneration system employing a gas-turbine generator set fueled with natural gas to serve local energy users. The site includes a mix of commercial, industrial and institutional facilities, as well as an existing steam plant with an associated steam distribution system, and is primarily owned and operated by a single corporation. The proposed system can produce 6950 kW of power while generating approximately 30,000 lb/hr of steam at 15 psig and 350°F. This

is roughly the equivalent of one-fourth of the peak capacity required at the Ford City site for both electricity and steam.

The economic analysis for the site yielded internal rates of return ranging from 25 to 35 percent. These results ignore any leveraging effects due to debt. It is clear that if a significant amount of debt were used to finance the initial investment, the rates of return based on equity would increase substantially. These results, then, represent the minimum returns assuming that all of the capital cost is equity funded. Based on this analysis, it is apparent that a cogeneration system at Ford City is both technically and economically feasible.

Conclusions

The Phase II feasibility studies were intended to define those factors which influence the feasibility of cogeneration facilities in the City of Chicago. It is apparent from the results of the case studies that significant potential for cogeneration development does exist at the three select sites. This potential, however, is largely dependent upon the continued economic viability of the industrial firms located in the three cogeneration development areas and would be greatly enhanced if new industries were to locate within these sites in response to incentives provided by discounted energy supplies. The economic feasibility of the refuse-fired facilities, particularly the Stockyards site, is also enhanced by the availability of publicly-assisted debt in the form of industrial development bonds. And in the case of the Ford City site, it is apparent

that the economic potential of the proposed facility is highly dependent upon the prices of natural gas and electricity over the next five to ten years, with the attractiveness of cogeneration increasing as electricity prices rise at a faster rate than prices of natural gas.

Since the City of Chicago faces the continuing problem of disposing of its municipal waste, it is recommended that the Stockyards and Calumet areas be considered as sites for future incineration/cogeneration facilities. These areas were previously sites for municipal incinerators, and they should again be considered as sites for central energy facilities that would produce low-cost steam and electricity for local industries, utilizing the municipal waste as fuel. The City should also explore the development potential that exists within these sites due to their designation as Enterprise Zones. The incentives provided by tax credits and exemptions and regulatory relief may encourage existing industries to expand their facilities and may persuade new industries to locate in these areas. A special attempt should be made by the City's Economic Development Department to identify industries particularly well-suited for cogeneration, such as the food processing industry, and to coordinate plans for the location of these industries with plans for the development of low-cost energy supply facilities such as refuse-fired central cogeneration systems.

With respect to the Ford City site, a substantial steam load already exists at the site for both industrial process needs and space heating requirements. However, this load is strongly tilted toward the winter and attempts should be made to shift it toward a level comparable to the annual electric load variation. This can be done in two ways. First, additional industrial process steam demands can be added by encouraging new tenants to the site or by expanding the site to include steam users such as the Katalco and Diamond Shamrock plants located north of the site. Second, changes could be made in the cooling system to shift from electrically driven comprehensive chillers to steam using absorptive chillers. This would have a tendency to increase summer steam demands which are currently non-existent for HVAC requirements.

The fundamental conclusion of the Ford City analysis is that an economically viable cogeneration system can be installed at the site. Uncertainties associated with future energy costs and capital costs can be reduced by a more detailed design study to serve as the basis for proceeding toward implementation of the proposed system. In addition, consideration should be given to alternative ownership strategies. Currently, the most obvious owner and operator of the system is the firm responsible for Ford City operations. Alternatives would include either the electric or gas utility ownership or a third party organization. The firm

which operates the facility should be large enough to use the tax savings which accrue in the early years of the project. These issues will be investigated in a more detailed study of the Ford City site planned by the City of Chicago in the upcoming year.

The Department of Planning will continue to explore the potential for cogeneration in Chicago as part of the City's comprehensive energy program. These research efforts will be coordinated with the Departments of Economic Development, Public Works, and Streets and Sanitation, so that public and private developments will be considered along with the City's long-range energy plans and waste disposal strategies. In addition, the City will continue to act as a facilitator between potential users of cogeneration facilities and local utilities, regulatory agencies, financial institutions and public and private development organizations in order to identify opportunities for cogeneration and to promote the development of viable projects in Chicago.

REFERENCES

1. Project Overview, Urban Integrated Industrial Cogeneration Systems Analysis Phase I Final Report, Volume 1, City of Chicago Department of Planning, December 1982.
2. Selecting and Evaluating Sites for Integrated Industrial Cogeneration Systems in the City of Chicago, Urban Integrated Industrial Cogeneration Systems Analysis Phase I Final Report, Volume 2, City of Chicago Department of Planning, December 1982.
3. Technology Assessment of Cogeneration and Alternative Fuels in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis Phase I Final Report, Volume 5, City of Chicago Department of Planning, December 1982.
4. Regulatory and Tax Aspects of Cogeneration Development in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis Phase I Final Report, Volume 3, City of Chicago Department of Planning, December 1982.
5. Robert W. Porter, "Load Requirements for Economical Cogenerated Energy Facilities in Chicago," Illinois Institute of Technology Energy Management Memorandum TM-82-2, November 1982.
6. Chicago Resource Recovery Study, Phase II, Environdine Engineers/City of Chicago Department of Public Works, June 1982.
7. Chicago's Enterprise Zones, Information Booklet, City of Chicago Department of Economic Development.
8. Environmental Aspects of Cogeneration Development in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis Phase I Final Report, Volume 4, City of Chicago Department of Planning, December 1982.
9. Illinois Pollution Control Board Rules and Regulations, Chapter 2: Air Pollution, February 1982.
10. Conversation with Christopher Romaine, Illinois Environmental Protection Agency, Air Quality Division, November 7, 1983.
11. Regulatory and Tax Aspects of Cogeneration Development in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis Phase I Final Report, Volume 3, City of Chicago Department of Planning, December 1982.
12. See Note 12, p. 28.

13. Z. Chaudary and Robert W. Porter, "Thermal Economic Analysis of Cogenerated Energy Recovery by Mass-Burning Modular Refuse Incinerators," Illinois Institute of Technology Energy Management Report TR-82-2, December 1982.
14. See Note 3.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix 1.1

URBAN INTEGRATED INDUSTRIAL
COGENERATION SYSTEMS ANALYSIS

PHASE I FINAL REPORT: PROJECT OVERVIEW

Report Prepared Under
U.S. Department of Energy Grant DE-F02-80CS40337

City of Chicago
Department of Planning

December 1982

PROJECT DESCRIPTION

The project "Urban Integrated Industrial Cogeneration Systems Analysis" addresses the identification and resolution of institutional, legal and economic issues of cogeneration in the urban environment. It also focuses on technical matters particularly, including the thermal-economic analysis of cogeneration within the context of regulation, financing, design, and optimization. The work is applied using a case study approach to cogeneration opportunities identified by a survey of industries and institutions in the City of Chicago in cooperation with Peoples Gas Company and Commonwealth Edison Company. The project attempts to bring to the attention of the industrial-commercial sector the opportunities and benefits of cogeneration in conserving energy and stimulating economic development.

TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	
Background	103
Scope of Project	106
Phase I Final Report	108
II. SELECTING AND EVALUATING SITES FOR INTEGRATED INDUSTRIAL COGENERATION SYSTEMS	
Overview	109
Inventory of Industrial Firms and Other Energy-Intensive Facilities	110
Energy Consumption	112
Cogeneration Site Evaluation	113
Summary	115
III. REGULATORY AND TAX ASPECTS OF COGENERATION DEVELOPMENT	
Overview	116
Regulatory Incentives for Cogeneration	117
Tax Laws Applicable to Cogeneration Projects and Equipment	119
Summary of Incentives for Cogeneration Development in Chicago	122

IV.	ENVIRONMENTAL ASPECTS OF COGENERATION DEVELOPMENT IN CHICAGO	
	Scope of Environmental Assessment	124
	Potential Environmental Effects of Cogeneration	125
	Environmental Regulation of Cogeneration Facilities	125
	Illinois Environmental Protection Agency Emission Estimates	128
V.	TECHNOLOGY ASSESSMENT OF COGENERATION AND ALTERNATIVE FUELS IN CHICAGO	
	Study Approach	129
	Results and Conclusions	130
	Recommendations	132
VI.	INDUSTRIAL COGENERATION POTENTIAL IN CHICAGO, 1980-2000	
	Scope of Market Evaluation	134
	Technical Market	135
	Economic Potential	135
	Conclusions	137
VII.	DEVELOPMENT ACTIVITIES	
	Purpose	138
	Presentation/Seminar Participants	138
	Survey of Industries and other Development Projects	140
	Publications	140

I. INTRODUCTION

Background

One of the more promising techniques for improving industrial energy productivity in the United States is the simultaneous production of mechanical (or electrical) power and process heat with on-site facilities. This approach, which was once known as combined heat and power but is now known by the more generic term, cogeneration, is by no means a new idea. During the first thirty years of this century, industrial cogeneration was quite common in a great many industries. However, as utility supplied electricity became readily available, reliable and relatively inexpensive on-site power production eventually became an unattractive investment for the majority of manufacturing plants.

In 1930, for example, self generation of power accounted for about 20 percent of the total electricity used in the United States. By 1975, however, industrial on-site power generation accounted for about 4 percent of total electricity demand. Of course, much of that reduction can be attributed to the phenomenal growth of electricity demand in the residential and commercial sectors. Nevertheless, today on-site generation of electricity accounts for about 9.3 percent of the total amount of electricity used in the manufacturing sector and 14.5 percent of that used in the five most energy intensive industries: food and kindred products, paper, chemicals, petroleum refining and primary metals. Even so, it is widely recognized that the potential for supplying a significant portion of the total electrical demand in

this country through cogeneration is very large. Unfortunately, tapping this resource economically remains a formidable task due to certain fundamental technical, economic and institutional issues.

Over the past several years the Federal government and, to a somewhat lesser extent, state governments have attempted to increase the economic potential of cogeneration by removing a plethora of institutional and economic barriers. These were seen as unnecessarily limiting the country's ability to control its energy use patterns in the face of expensive energy. Legislation was enacted as part of the National Energy Act of 1978 to correct many of these limiting factors. For example, the Public Utility Regulatory Policies Act (PURPA) of 1978 was designed not only to require electrical utilities to interconnect with qualified cogenerators and small power producers, but also to pay an equitable amount for their power which would include not only an allowance for fuel not burned but also a credit for avoided capacity additions due to the presence of the facility. Qualifying cogeneration facilities were exempted from other legislation which required that power and steam producers use coal rather than oil or gas (Fuel Use Act of 1978). Further, qualifying facilities were made eligible for energy tax credits which would enhance their economic attractiveness in essentially all sectors of the energy using economy.

On the state level, most of the impetus for fostering cogeneration development has resided with public utility commissions. These have usually been commissions in states which face rapidly increasing electricity rates because of a strong dependence on oil or natural gas for utility fuel. Included are most states in the northeast plus Minnesota, Wisconsin, Texas and most notably California. In California, cogeneration has been viewed as a viable alternative to new coal- or nuclear-based generating facilities. Desirable side effects include reduced environmental impacts, especially on air, and a diversity of electricity production which could theoretically make the entire system more reliable and less vulnerable to system-wide failure. Another, perhaps unintended, side effect is that the electricity generating industry will somewhat approximate a free market, thus helping to keep consumer costs down.

On the local level, specific actions to encourage cogeneration development have not been widespread. Much effort, under the sponsorship of the Department of Energy, has been expended to encourage district heating and integrated community energy systems in such places as Trenton, New Jersey; New Orleans; Detroit; Baltimore; Washington, D.C.; and Akron, Ohio. These efforts have met with limited success. Probably the most notable success story is that of St. Paul, Minnesota, where the mayor has been quite active in promoting energy conservation measures. The St. Paul project was initiated by converting an abandoned power plant on the Mississippi River near the University of Minnesota to a cogeneration facility. The district heating concept has since been

extended to assist in the development of a nearby light industrial complex. This effort indicates that local government can play an active role in promoting energy conservation measures such as cogeneration and, perhaps, use it as a centerpiece for reindustrialization.

Most recently, with a grant from the Department of Energy, the City of Chicago undertook the Urban Integrated Industrial Cogeneration Systems Analysis (UIICSA). The purpose of this multi-phase effort is to: 1) develop an "energy presence" for the City, 2) evaluate specific industrial sites and areas suitable for cogeneration, 3) identify specific projects; and 4) with the cooperation of interested manufacturing firms, prepare plans for the development of one or more sites. One of the objectives is to discover if City sponsored and encouraged cogeneration would help to preserve existing industry and spur new industrial development in Chicago. It is hoped that the experience gained in a successful program of this nature would be transferable to other cities facing similar problems.

Scope of Project

The primary objective of the UIICSA is to identify specific cogeneration projects which the City can help implement. Success of the project is largely dependent upon the City's "brokering" role between financial institutions, governmental agencies, utilities, manufacturers and equipment suppliers to identify and promote the deployment of cogeneration and other energy conservation techniques. With the cooperation of local

universities, most notably the Illinois Institute of Technology and the Energy Resources Center at the University of Illinois in Chicago, the City has identified not only the most likely industrial sites which may effectively use cogeneration, but also nearby hospitals, schools, college campuses and public housing facilities which could be integrated into a central system serving a specific area, such as an industrial park or an industrial development area.

Subsequent studies conducted by the Illinois Institute of Technology focused on the technical and economic evaluation of industrial sites in the city showing the greatest potential for cogeneration. These included not only single large manufacturing plants but also groupings of plants such as those in the Goose Island and former Stockyards areas. The City also promoted the project through seminars conducted for industrial managers, local industrial development organizations and commercial developers.

One of the most important tasks of the UIICSA is to identify the impact of Federal, state and local laws, regulations and ordinances on cogeneration development in Chicago. Of particular interest are incentives and disincentives imbedded in legislation at the Federal level such as PURPA, the Fuel Use Act and the more recently enacted tax laws of 1981 and 1982. Results of these analyses and evaluations indicate that there are substantial

incentives inherent in these laws. However, limitations on utility financial involvement, the disappearance of special energy tax credits and the new accelerated depreciation schedules effective at the end of 1982 may hamper that development.

Phase I Final Report

The purpose of this report is to summarize the activities and findings of Phase I of the UIICSA. Detailed reports covering this work are included in the following volumes of the Phase I Final Report:

- Volume 2. SELECTING AND EVALUATING SITES
 FOR INTEGRATED INDUSTRIAL COGENERATION
 SYSTEMS IN THE CITY OF CHICAGO
- Volume 3. REGULATORY AND TAX ASPECTS OF COGENERATION
 DEVELOPMENT IN CHICAGO
- Volume 4. ENVIRONMENTAL ASPECTS OF COGENERATION
 DEVELOPMENT IN CHICAGO
- Volume 5. TECHNOLOGY ASSESSMENT OF COGENERATION
 AND ALTERNATIVE FUELS IN CHICAGO
- Volume 6. INDUSTRIAL COGENERATION POTENTIAL IN
 CHICAGO, 1980-2000

II. SELECTING AND EVALUATING SITES FOR INTEGRATED INDUSTRIAL COGENERATION SYSTEMS

Overview

Industrial areas with large and relatively constant base-load thermal energy requirements offer the greatest potential for cogeneration development. Thermal energy demand is the primary consideration, since owners and operators of cogeneration facilities may negotiate buy-sell arrangements with the electric utilities to match their electric loads. In addition, facilities which use thermal energy for space heating or cooling, such as commercial and institutional buildings, may also be suitable for cogeneration, particularly those located close to energy-intensive industrial firms.

Previous studies of cogeneration potential have focused on specific industries and single, large energy-intensive firms. However, it is also possible to screen and evaluate "sites" within a larger geographical context, such as a city or metropolitan area. A major objective of Phase I of the UIICSA was to identify potential industries and sites for cogeneration development in the City of Chicago and to provide a framework for more detailed site-specific feasibility studies to follow in Phase II of the project.

Inventory of Industrial Firms and Other Energy-Intensive Facilities

One of the initial steps undertaken in the site selection process was the development of an inventory of industrial firms and other energy-intensive facilities with cogeneration potential in Chicago. Toward this end, a comprehensive list of 111 energy-intensive industries, identified by Standard Industrial Classification (SIC) code, was compiled by project researchers. These were separated into two groups: 1) primary thermal users, whose thermal energy use was considered to be of a baseload character; and 2) co-located facilities, whose thermal energy requirements were more likely to be for space heating. This latter group was included because of the close location of these facilities to energy intensive firms which could serve as the core of potential cogeneration systems.

The methodology used to identify and evaluate potential cogeneration sites in Chicago consisted of three major phases:

- 1) description of the geographical distribution of industrial firms, commercial facilities, public buildings and institutional complexes in Chicago with cogeneration potential;
- 2) definition of the energy use patterns for these firms and facilities; and
- 3) selection and evaluation of candidate sites particularly well-suited for industrial cogeneration.

The Duns Market Identifier (DMI) file was the major source of information describing energy-intensive industrial firms in Chicago. The file, compiled by Dun and Bradstreet, provided a listing of firms, addresses, SIC codes and other firm characteristics, including annual sales volume and number of employees. The list of industries in Chicago with SIC codes indicating primary thermal users was screened to exclude sites (primarily offices and warehouses) which did not engage in processing activities. The inventory was also screened to exclude smaller firms. An annual sales figure of \$300,000 or more was used to distinguish between small and large firms.

Co-located facilities, which include educational, institutional and commercial buildings, generally use large amounts of thermal energy for space heating. A supplemental inventory of co-located facilities was compiled by the City of Chicago Department of Planning, and approximately 1,600 such facilities were selected for consideration in evaluating potential cogeneration sites.

In order to determine the distribution of energy-intensive industrial firms and other facilities in Chicago, the project inventory was merged with the metropolitan area census geography file through the ADMATCH process. This process compared street addresses for any data set with records maintained by the U.S. Bureau of Census, which included census block and tract numbers

consistent with metropolitan area census geography. Consequently, the data could be mapped, aggregated into various geographical groupings and matched with similar data sets.

In 1980, the City of Chicago had a combined total of 1,629 large primary thermal users and co-located facilities. Forty-three percent of the 867 census tracts had neither type. These areas were not considered further in the site selection process. However, 269 census tracts had two or more firms and facilities, and 30 of these had ten or more. Areas with concentrations of energy-intensive firms and facilities were identified in the Loop and adjacent communities, in corridors with CHA high-rise structures, along the North and South Branches of the Chicago River and near Calumet Harbor.

Energy Consumption

The second phase of the cogeneration site selection process focused on defining energy use characteristics for firms and facilities included in the UIICSA inventory. To accomplish this, energy consumption data were provided by Commonwealth Edison and Peoples Gas Light and Coke Company. In order to obtain the energy data in a usable form, each utility's customer address file was ADMATCHed with the geocoded inventory of firms and co-located facilities so that the account records could be merged with the metropolitan area census format. The firms and facilities were then grouped according to compatible energy use type and proximity within census tracts. Each group included at least two firms and/or facilities in order to prevent the disclosure of any single

firm's billing history. The utilities then provided 1980 annual and monthly energy use data for each group. From this information, energy use profiles were produced for the firms and facilities included in the UIICSA inventory. In addition, natural gas consumption data were mapped to illustrate the level and distribution of thermal energy use in Chicago.

The inventory of firms and facilities, complete with energy use information, was again screened for the purpose of identifying potential cogeneration sites for further study. Energy use characteristics served as the primary screening criteria, with secondary consideration given to the geographical distribution of firms and facilities in a given area. Thirty-four sites, consisting of approximately 300 firms and facilities, were selected as the most favorable for further evaluation.

Cogeneration Site Evaluation

The final stage of the UIICSA site selection process involved the profiling and evaluation of potential cogeneration sites. The sites were evaluated according to criteria related to requirements of particular cogeneration technologies and to opportunities for industrial development. The objective of this task was to evaluate and compare the potential sites and to identify the most promising sites for further detailed feasibility studies in Phase II of the project.

The criteria applied to the site selection included: 1) factors describing various measures of energy consumption, 2) average distance among facilities within the site, 3) types of facilities located at the site, 4) the manner in which energy is used by those facilities, 5) state-of-repair and distribution of existing energy systems such as central steam facilities, 6) the amount of vacant land located within or near the site, 7) the existence of geographical barriers within the site, 8) accessibility of the site to major transportation thoroughfares and 9) plans for industrial, commercial or other major public development in the area.

A hierarchical, linear-weighted model was used to determine the relative suitability of the 34 candidate sites. Each of the components and variables was first transformed, or mapped, on a scale of 0 to 5 which represented critical values for the evaluation.

Following the application of the site evaluation procedure to the 34 candidate sites, it was possible to rank the sites and determine a priority for later feasibility studies. The sites ranged in suitability from a high score of 4.16 (maximum suitability index = 5.0) to a low score of 1.36. Only eight sites received scores below the mean index of 2.26. A subsequent review of these sites resulted in 21 sites being selected for further study. A summary of these sites is included in Volume 5, Table 1-1 of the UIICSA Final Report.

Summary

The site selection methodology is a relatively quick, inexpensive and direct procedure for identifying potential sites for cogeneration development. The basic inventory of primary thermal users and co-located facilities can be compiled from readily available sources, and metropolitan area census geographies are common to all large cities and urban areas in the United States. The methodology can be applied to any metropolitan area provided the utilities agree to supply energy use data. If not, estimates of energy use will need to be provided for generic industrial firms and other facilities in lieu of customer billing histories.

The site evaluation model compares candidate sites according to their relative suitability for industrial cogeneration. This information can be used as a guide for further detailed, site-specific feasibility studies and for designing strategies which link cogeneration with other economic development programs.

III. REGULATORY AND TAX ASPECTS OF COGENERATION DEVELOPMENT

Overview

One of the major activities undertaken during Phase I of the industrial cogeneration project was the analysis of various legal aspects of cogeneration. This analysis involved an evaluation of Federal, state and local regulatory and financial incentives and restrictions affecting the planning and development of cogeneration projects in the City of Chicago.

Two areas have been of particular importance in the regulatory and tax analysis. The first is the impact of the Public Utility Regulatory Policies Act of 1978 which provides a market for power sales by cogenerators and exempts them from utility-type regulation. The second concerns the recently enacted changes to the Internal Revenue Code which provide tax-related incentives for cogeneration project financing, including tax credits, accelerated depreciation and modified leasing rules. These and other changes in law at the Federal level may greatly affect the economic viability of, and institutional arrangements for, cogeneration projects in Chicago.

Other regulatory areas were also analyzed for their effect on cogeneration development. These include fuel use restrictions on the use of oil or natural gas in cogeneration facilities, the impact of higher natural gas prices on project economics and possible advantages of the cogeneration exemption from incremental pricing under the Natural Gas Policy Act.

Finally, in order to gain a better understanding of the economic feasibility of cogeneration in the Chicago area, the Department of Planning and the Illinois Institute of Technology conducted a number of case studies which apply alternate ownership configurations and financing options to the analysis of specific projects, taking into account the legal and institutional framework to which these projects must conform. Industrial and commercial examples were analyzed using tax leasing and sale-leaseback arrangements, as well as 100 percent equity financing.

Regulatory Incentives for Cogeneration

The Public Utility Regulatory Policies Act of 1978 (PURPA) requires the Federal Energy Regulatory Commission (FERC) to issue rules for the encouragement of cogeneration. These rules provide assurances that qualifying cogenerators are able to interconnect with electric utilities, to sell electricity to electric utilities and to receive prices for sales to electric utilities which are just and reasonable to the consumers of the electric utility, non-discriminatory toward the cogenerator and in the public interest.

The FERC regulations provide a number of advantages for qualifying cogeneration facilities. First, the rules provide for the exemption of these facilities from the Federal Power Act (FPA), the Public Utility Holding Company Act (PUHCA) and all state public utility regulations. The FPA and PUHCA place significant limitations on utilities concerning such things as allowable rates, accounting practices, securities issuance and financial and administrative organization. Generally, state public utility

regulations are equally extensive. Exemption under PURPA from these various restrictions makes operation of a cogeneration facility considerably less burdensome than it would be otherwise.

Second, qualifying cogenerators are assured a market for their power. The Commission's rules require that each electric utility purchase electricity offered to it from these facilities at a price which reflects the costs the utility avoids by purchasing the electricity instead of either generating the power itself or buying the power from other utilities. A facility has the option of selling all of the electricity it generates to the utility at the utility's avoided costs and buying back what it needs at the utility's retail rates, or selling only that amount of electricity produced in excess of its needs.

Third, qualifying facilities are assured interconnected operation with utilities and non-discriminatory rates for back-up power that may be required.

On April 15, 1981, the Illinois Commerce Commission (ICC) issued rules implementing the provisions of PURPA for the purchase and sale of electricity from cogenerators in Illinois. These rules generally follow the Federal regulations described above.

Other regulatory incentives for cogeneration are included in the Powerplant and Industrial Fuel Use Act (FUA), the Natural Gas Policy Act (NGPA) in addition to the PURPA program. The FUA, which requires newly constructed powerplants and major fuel burning installations to burn fuel other than natural gas, allows for an exemption for cogeneration facilities. The NGPA, which requires industrial facilities burning natural gas to pay a surcharge, also exempts qualified cogeneration facilities. In addition, cogeneration facilities which qualify under the PURPA program are exempted from the incremental pricing surcharge on natural gas.

Tax Laws Applicable to Cogeneration Projects and Equipment

Federal income tax laws may provide significant economic benefits for investors in projects and equipment involving cogeneration, but careful planning of these projects is essential since the recently-enacted Economic Recovery Tax Act of 1981 (ERTA) and the Tax Equity and Fiscal Responsibility Act of 1982 (TEFRA) have affected the extent of these benefits.

Investors in energy-related equipment and facilities may qualify for tax credits under the Internal Revenue Code. Under the Code, taxpayers may claim an investment tax credit (ITC) equal to 10% of their qualified investment in certain cogeneration property. The Code also permits taxpayers to claim an additional energy tax credit (ETC) generally equal to 10 percent or 15 percent of the taxpayer's qualified investment in statutorily-defined energy property. However, under present law only cogeneration property placed in service by December 31, 1982 qualifies for the 10 percent

ETC. Exceptions are made for certain cogeneration projects having long-term construction periods which may be eligible for the ETC if placed in service by December 31, 1990. Legislation to extend the eligibility period for certain types of energy property, though not specifically for cogeneration property, is presently pending before Congress. The prospects for passage of this legislation are unclear since they will depend upon economic and budgeting constraints and the perception by the Congress of energy as a national priority.

Several important restrictions are placed on the eligibility of certain types of property and the extent of benefits provided for the ITC and ETC. Property falling within the definition of "public utility property" generally cannot qualify as energy property and qualifies the taxpayer only for the ITC. Moreover, boilers fueled primarily by petroleum or petroleum products, including natural gas, generally do not qualify for either the ITC or ETC if they are used in manufacturing, processing or other industrial facilities, or if they constitute public utility property. In addition, property owned or used by governmental entities or by tax-exempt organizations does not qualify for either the ITC or ETC. Finally, under new rules aided by the TEFRA, a taxpayer must now reduce his basis in property by 50 percent of the amount of any ITC or ETC claimed with respect to the property. Thus, hereafter Accelerated Cost Recovery System deductions will be calculated on a taxpayer's basis in property which is reduced by one-half of the ITC and ETC allowed for the property.

The Accelerated Cost Recovery System (ACRS) added by the ERTA replaced the existing system of depreciation, including the Asset Depreciation Range (ADR) class life system, for property placed in service after 1980. The net effect of the ACRS system will be to permit investors in energy-related equipment and facilities to recover capital costs for most tangible depreciable property at accelerated rates over shortened statutory recovery periods. However, new provisions added by the TEFRA also impose a significant "double-dipping" limitation on ACRS deductions with respect to property financed with tax-exempt IDBs. A taxpayer is denied any ACRS deductions to the extent that recovery property is financed with the proceeds of tax-exempt IDBs. In lieu of ACRS deductions, the taxpayer may recover the cost of such property only by using the straight-line method of depreciation over the ACRS life of the property.

Additional tax benefits available to investors in energy-related equipment and facilities are deductions for interest incurred to finance the property as well as taxes and other expenses associated with the property. An owner who leases property is generally entitled to all these benefits, and thus a lease can serve to transfer tax benefits attached to ownership of property to nominal or passive investor/lessors. As a practical matter, users of energy-related equipment and facilities may be able to "sell" tax benefits associated with the property as a means of both lowering their effective cost and attracting equity investors.

Summary of Incentives for Cogeneration Development in Chicago

The analysis of Federal incentives for cogeneration development applicable to Chicago suggests that carefully planned projects are economically worthwhile. The most significant benefit associated with cogeneration is the lower overall price paid by participants in such projects for electricity and thermal energy. In addition, Federal law provides exemptions from restrictions on fuel use and fuel surcharges and significant tax benefits for cogeneration projects and equipment.

With regard to PURPA, it is important to note that the Illinois Commerce Commission's implementation allows a cogenerator to shift from selling only excess power to selling the facility's entire electric output and buying back the amount needed for the facility's internal requirements at applicable retail rates. Commonwealth Edison's retail electricity rates are currently higher than its buy-back rates, and therefore a cogenerator in Chicago would want to sell only that electricity in excess of the facility's needs. To the extent that future buy-back rates rise higher than retail rates, a cogenerator may want to sell the facility's entire output to the utility and purchase its needs at the lower retail rates.

On balance, it appears that efficiencies to be gained from operation in the cogeneration mode provide sound investment opportunities for industries in Chicago. Projects must be carefully planned to ensure that they are fundamentally sound and will remain sound as retail electricity costs and buy-back rates, as well as other programs discussed herein, change over time.

IV. ENVIRONMENTAL ASPECTS OF COGENERATION DEVELOPMENT IN CHICAGO

Scope of Environmental Assessment

An important part of the UIICSA regulatory analysis was the assessment of environmental aspects of cogeneration development in Chicago. Environmental issues arise primarily as a result of the use of fossil fuels and municipal refuse in cogeneration systems. There are contending views as to the effects cogeneration may have on the environment, particularly with respect to air quality. Cogeneration is generally viewed as having the potential to enhance air quality since these systems produce energy more efficiently than conventional energy systems and thereby produce less pollution overall. However, concern has arisen over the potential decentralization of energy production and fuel emissions that could result from expanded cogeneration development. It is therefore important to assess how cogeneration may effect the environment and to ensure that owners and operators of these facilities are aware of and comply with environmental protection policies and regulations designed to control adverse effects.

The environmental assessment included a review of environmental concerns related to the operation of cogeneration facilities in Chicago. In addition, the environmental regulations and permitting processes applicable to these facilities were identified. Finally, since the environmental effects and regulations will vary according to the technology and fuel utilized

in a particular application, the assessment also included emission estimates by the Illinois Environmental Protection Agency of five alternate cogeneration systems considered for the Chicago area.

Potential Environmental Effects of Cogeneration

While an environmental analysis may involve a broad range of considerations, ranging from resource extraction to waste disposal, this analysis focused upon the particular environmental concerns related to the operation of cogeneration facilities in Chicago. The major potential environmental impact is the emission of air pollutants from facilities burning fossil fuel or municipal refuse. Other important environmental considerations include waste water discharge, solid waste disposal, foul odors and unsightliness of municipal refuse, noise levels of operation and the inconvenience to a community resulting from the transport of fuel to and from a cogeneration site.

Environmental Regulation of Cogeneration Facilities

The single most important piece of environmental legislation affecting cogeneration is the Clean Air Act established by Congress in 1970 and amended in 1977. The purpose of the Clean Air Act is to protect public health and property from the harmful effects of air pollution through the improvement and maintenance of ambient air quality. Under the Act, the Environmental Protection Agency was authorized to develop national air quality standards and to establish technology requirements to meet those standards. Thus, the National Ambient Air Quality Standards (NAAQS) were formulated for seven pollutants, including total suspended particulates (TSP),

sulfur dioxide (SO₂), carbon monoxide (CO), nitrogen oxide (NO_x), photochemicals, hydrocarbons and lead. Under the Act, states were assigned the responsibility of developing and administering programs to meet the NAAQS. Toward this end, states are required to prepare State Implementation Plans (SIP) for achieving and maintaining ambient air quality.

The Clean Air Act addresses five major areas of consideration applicable to cogeneration facilities in Chicago, including: 1) New Source Performance Standards, 2) attainment/nonattainment status of the areas in which cogeneration facilities would be located, 3) designation of facilities as major new or major modification to major sources of pollution, 4) determination of whether the facilities would be subject to the Prevention of Significant Deterioration (PSD) review or Best Available Control Technology (BACT) requirements and 5) determination of whether the facility would be subject to the Lowest Achievable Emission Rate (LAER) program.

The Illinois Environmental Protection Agency (IEPA) has the legal authority to administer regulations and prosecute violators of the Clean Air Act. The IEPA enforces air pollution regulations which have been established by the Illinois Pollution Control Board through a state permitting program. Under the program, a cogenerator is required to apply for a permit for the construction or operation of any new emission source or pollution control equipment and for the modification of any existing source of pollution.

The IEPA has established operating requirements for stationary sources which incorporate the Federal New Source Performance Standards. In addition, emission standards have been established for stationary fuel combustion source emissions which include: particulates, SO₂, NO_x, CO and visual emissions.

The City of Chicago's environmental protection policy was established in the 1970 Environmental Control Ordinance. The provisions of this ordinance are stated in Chapter 17 of the City of Chicago Building Code. Local government control is also exercised through the enforcement of zoning and building codes based on the Environmental Control Ordinance. The Environmental Control Division of the Department of Inspectional Services and the Department of Consumer Services are responsible for enforcing these provisions by requiring construction and operation permits for all building projects in the city.

Other permits may be required depending on the location and needs of the cogeneration facility. These may include permits for waste discharge, tanks, compressors, driveways, sewers, water service and demolition. Along with the permitting requirements, Codes of Recommended Practices were established for fossil fuel burning and municipal refuse burning in the city.

Illinois Environmental Protection Agency
Emission Estimates

The analysis of potential emission levels produced by various technologies and fuels included a review by the Illinois Environmental Protection Agency (IEPA) of five cogeneration options considered for the Chicago area. These facilities include: 1) a natural gas, dual-fuel diesel, 2) a natural gas-fired gas turbine, 3) a refuse-fired steam turbine, 4) a natural gas-fired steam turbine and 5) a low-sulfur coal-fired steam turbine.

According to the IEPA review, a municipal refuse or low-sulfur coal-fired facility would have the greatest potential to exceed air pollution emission limits. While a natural gas, dual-fuel diesel facility would also be likely to exceed the limits, such a facility is not presently considered to be economically feasible in the Chicago area. The natural gas-fired turbine facility would produce the lowest level of emissions; but this system was also considered to be uneconomical in the present case.

The emission estimates prepared by the IEPA can be used to identify the environmental regulations which would apply to cogeneration facilities in Chicago. However, a conclusive analysis would require additional information concerning existing emissions at the proposed site. Nonetheless, with proper design, the application of air pollution control equipment and the availability of exemptions from local restrictions, the environmental regulations should not inhibit the development of cogeneration facilities in Chicago.

V. TECHNOLOGY ASSESSMENT OF COGENERATION AND ALTERNATIVE FUELS IN CHICAGO

Study Approach

A major activity undertaken during Phase I of the UIICSA was the technology assessment carried out by the Illinois Institute of Technology. Particular attention was given to thermal-economic aspects of cogeneration and alternative fuels as they affect the feasibility of projects in light of contemporary legislation and financial arrangements.

The approach was founded on the identification of technologies and relevant industries by previous U.S. DOE studies. However, recognition was given to local and site-specific conditions as well as recent legislation, including the National Energy Act and the Tax Equity and Financial Responsibility Act of 1982. Technologies included fired boilers using steam turbines and fueled by natural gas, low-sulphur coal or refuse, and gas turbines and dual-fuel diesels employing natural gas. Relevant industries in Chicago are varied but predominate within the food process classification.

Performance and cost data for the project were provided mainly by Sargent and Lundy (S & L) Engineers. Data on modular refuse incinerators of the water-wall type were provided by Basic Environmental Engineering Co., Inc. A literature survey was used to provide miscellaneous costs such as that of operation and maintenance, etc. A study by S & L, as substantiated by a literature survey, yielded the basis for fuel and electrical energy projections.

The approach to economic assessment was based on rate of return on incremental investment being at least a "threshold" or "hurdle" value. In order to reduce uncertainty of general inflation, real dollars of constant purchasing power were employed. The favorable effects of alternative financing including debt financing and leveraged leasing were also studied, and the analysis yielded levelized annual savings which can be translated into product cost reduction.

A series of case studies was performed including a single direct-heat user, a small single steam user, a central refuse-fired cogeneration plant, a small central cogeneration plant, a medium central cogeneration plant and two commercial facilities. A "generic" or "greenfield" study was also performed using typical parameters in such a manner that the user requirements for viable technologies were determined.

Results and Conclusions

The results of the case studies indicate that the best prospect for alternate fuels and cogeneration in Chicago is in a refuse-fired cogeneration facility. Using two to five modular incinerators, the system would have a rated installed refuse capacity of 300 to 750 TPD and accordingly from 52,000 to 131,000 lbm/hr of 150-psig steam and 1.5 to 3.75 MW(e) of electricity, respectively. It is felt that at least two modular units are needed to provide reliable operation whereas the optimum capacity for a more-or-less-typical load profile was found to be five units.

Five sites in Chicago have been identified as good candidates for refuse-fired cogeneration. The main problem is organizing users into a system of sufficiently small distribution distance. Many other sites could become viable if sufficiently large thermal load is added in the form of new users. An additional problem is evaluating the impact of the proposal on Chicago's current and planned refuse-disposal system.

The case of low-sulphur-coal-fired cogeneration is potentially viable at one site if the present equipment is obsolete. If a sufficiently large new load could be added to any of the other sites, then low-sulphur coal would be a viable fuel in those cases as well, presuming that purchases of new (gas-fired) equipment were to be displaced.

The case of a large gas-turbine plant employing direct heat should also be considered in the event a sufficiently large thermal load can be identified, at least the equivalent of 52 MMBtuh (1 Mars turbine; 296,000 lbm/hr of 764°F combustion products).

It appears as though a large commercial facility such as for the North Loop would be viable if a sufficiently low return on investment were acceptable. This might be justified by the energy savings that could be used to attract tenants. However, the problem of an extended phase-in period of startup remains.

A basic problem for cogeneration is the low value of electricity due to the local utility's extensive use of nuclear and coal-fired generation. Thus, it is difficult to justify the use of coal, much less natural gas. Currently, we expect electricity prices to move at the general inflation rate and fossil-fuel prices to move at 1.7% (coal) to 2.0% (natural gas) above general inflation. Should this differential escalation narrow or be reversed, then fossil-fired cogeneration could become viable in Chicago. Nevertheless, refuse is and likely would remain a viable fuel. Further, the proposed incinerator plants would ease the need for local land fill. A decrease in capital cost of cogeneration facilities would ease the difficulty of implementing the technology in any case.

Recommendations

It is recommended that the five currently viable sites be further investigated to see if sufficient interest can be developed among existing industries for refuse-fired cogeneration in the form of a single user or a central energy facility. However, approximately 42,000 lbm/hr of available base load of 150-psig steam (or equivalent) would suffice if it can be located on a three to seven mile (or less) distribution system depending on whether a credit for conventional equipment can be taken. Electrical output is sufficiently small for such a minimal facility (1.2 MW(e)) and could be used to displace purchases assuming mutual ownership by the users. A larger system could be built up using the modular concept, depending on the available load. A variety of ownership and financing arrangements appear to be viable for the refuse-fired

case and can be tailored to the local situation.

Other sites are also potentially viable in the event the thermal load can be increased in the form of new users. These users could be either industries or institutions missed in the current survey or those newly locating on the site in question. However, in the absence of such new users, the aforementioned five sites appear to be the best prospects. New loads can be added to them as well, thereby allowing greater flexibility during the period of phase-in until full startup can be achieved.

VI. INDUSTRIAL COGENERATION POTENTIAL IN CHICAGO, 1980-2000

Scope of Market Evaluation

Chicago has been widely recognized for over a century as a leading industrial center in both the United States and the world. During the past twenty years various technological and economic factors have acted to shift Chicago's economy slowly toward a service orientation with a resultant decrease in its industrial base. One of the factors which has been identified as contributing to the erosion of the industrial base is the cost of energy which has risen dramatically in the past decade on both an absolute and real basis. To help counteract the energy cost rise, the UIICSA has investigated the ways, means and opportunities for encouraging industrial-based cogeneration as a part of its reindustrialization strategy.

The technical and economic market study was an attempt to estimate the overall potential for cogeneration under current technological and economic assumptions. Other studies have indicated either no economic potential or a large potential. These widely varying results came about because of fundamental differences in economic assumptions. The results of this study, limited to fossil fuels, are not very encouraging, indicating that a small market at best exists on an individual plant level. However, it also indicates that if current trends continue over the next few years regarding the relative increases in the prices of electricity and natural gas, the economic potential could grow dramatically even if electrical utility buyback rates remain

significantly below industrial retail levels. As noted in the previous chapter, the technology assessment concluded that refuse-fired cogeneration plants are viable at five sites involving a total of 30 industries and institutions.

Technical Market:

The City of Chicago has been estimated to be the home of over 12,000 manufacturing establishments as recently as 1979. Of these, only 280 sites were found to have the requisite technical characteristics to accommodate a cogeneration system. This number of plant sites was further reduced to a maximum of 88 systems having a total electrical generating capacity of 982.87 MW. This technical market, if realized, could save up to 10.932×10^{12} Btu/year in total energy usage in Chicago. Since many of these systems would be natural gas-fired, this would represent a dramatic shift in sales from the local electric utility to the gas utility.

Economic Potential:

The economic market for cogeneration is strongly dependent upon the differential cost between electricity and fuel. The equipment essentially represents a transactional cost to convert one form of energy (fuel) to another, more useful, form (electricity and heat). If this price difference is not large enough, the system would not be economically viable. (This is a fundamental problem of the synfuels industry.) Under the economic parameters operative in 1981, including average industrial electricity and natural gas prices, operating and maintenance costs, capital costs, tax credits, and accelerated depreciation

schedules, the economic potential for cogeneration in Chicago is quite limited. Although 28 sites were identified as having a positive Return on Investment (ROI); only five were found to have an ROI exceeding 10 percent in real dollars (i.e. discounted for inflation). Since no site was found to have an ROI over 15 percent, then it is not likely that any systems will be installed.

It was also found that incentives such as the 10 percent investment tax credit (ITC) seem to have little effect on the economic viability of the project. Since these projects tend to have long useful lives, it appears that the ITC would only help marginal plants. The accelerated depreciation schedules now in effect for cogeneration systems, however, seem to have a much stronger effect on the economic viability of these plants.

Perhaps the strongest effect on cogeneration system rates of return is the differential price between electricity and fuel, in this case natural gas. Between 1981 and 1982, the industrial price of natural gas increased by 12 percent while the price of electricity increased by 17 percent. Using these prices, with the same capital costs, increased the number of sites with positive ROIs to 39, while two plants showed ROIs greater than 15 percent.

Conclusions

The main conclusions which can be made from the results of this study to date are:

- . Because of its large industrial base, the potential for cogeneration development in Chicago is substantial and may approach or exceed 1000 MW(e) in capacity.
- . Incentives such as tax credits do not seem to have a strong effect on economic viability. Accelerated depreciation schedules, however, seem to be much more effective.
- . Economic viability of cogeneration systems is strongly dependent upon the differential price between fuel and electricity. Since natural gas is a likely fuel for use in Chicago cogeneration systems, this price is most crucial. Current conventional wisdom indicates that natural gas prices will increase faster than electricity prices, although recent history indicates otherwise.

It should be kept in mind that this study considered only conventional technologies and conventional fuels at individual plant sites. Alternative fuels, such as urban or industrial wastes, and larger systems involving several plant sites in "cascaded" energy arrays may well prove to be strong economic choices and should not be discounted. Identifying those opportunities could help to bring about significant energy cost reductions and should be a key factor in the industrial development strategy for Chicago.

VII. DEVELOPMENT ACTIVITIES

Purpose

A primary objective of the UIICSA is to identify specific cogeneration projects which the City of Chicago can help implement. Success of the project to a large extent depends upon the City's "brokering" role between financial institutions, government agencies, utilities, manufacturers, developers and equipment suppliers for the purpose of identifying and promoting the development of cogeneration and other energy conservation techniques in Chicago. Toward this end, the City, with the assistance of other project participants, conducted a number of cogeneration presentations and seminars for industrial managers, industrial development organizations, commercial developers, investment bankers and others interested in cogeneration potential in Chicago. The forums provided an opportunity to educate these groups as to the benefits of cogeneration and to share project findings.

Presentation/Seminar Participants

The following organizations participated in one or more of the cogeneration presentations and seminars:

Acme Frame Products
Amforge, Inc.
Arrowhead Heating and Cooling
A.G. Becker, Inc.
Berger Realty
Best Foods
Nich Beucher and Sons
Cameo Container Corporation
Cargill, Inc.
Center for Neighborhood Technology
Chambers Gasket

Chicago Association of Commerce & Industry
 City of Chicago Department of Economic Development
 City of Chicago Department of Planning
 City of Chicago Department of Public Works
 City of Chicago Department of Streets & Sanitation
 City of Chicago Office of Budget & Management
 City of Chicago Office of the Mayor
 Chicago Tribune
 Clayton Manufacturing
 Cogeneration Development Corporation
 Commonwealth Edison
 Continental Illinois Bank and Trust Company of Chicago
 Cosentini and Associates
 Energy Resources Center of the University of Illinois
 Fauske and Associates, Inc.
 Fiffield, Palmer and Company
 First National Bank of Chicago
 Fleetwood Realty
 Ford Motor Company
 Gas Research Institute
 General Mills
 Greater North Pulaski Development Corporation
 Griffith labs U.S.A.
 W.F. Hall Company
 Hunt-Wesson Foods
 Illinois Housing Development Authority
 Illinois Institute of Technology
 State of Illinois Governor's Office of Consumer Services
 Industrial Development Corporation
 Inland Steel
 Lester B. Knight and Associates
 Medill News Service
 Metropolitan Structures, Inc.
 Mid-America Appraisal and Research Corporation
 Peoples Gas Light and Coke Company
 Pioneer Bank and Trust Company
 Playskool, Inc.
 Potential Energy
 Prescott, Ball and Turben
 Pride Container
 Reedy Industries
 Republic Steel
 Ronzoni Macaroni
 Arthur Rubloff and Company
 Santa Fe Industries
 Sargent and Lundy Engineers
 The Seraco Group
 Stein, Peterson and Company
 Dan Shannon and Company
 Tishman Midwest Management

U.S. Department of Energy
United States Steel Corporation
Van Ness, Feldman, Sutcliffe, Curtis & Levenberg
Woodstock Institute

Survey of Industries and Other Development Projects

Another major activity undertaken during Phase I of the UIICSA was the surveying of industries and other facilities where cogeneration may be applied. This involved the distribution of letters and detailed questionnaires to approximately 60 firms and facilities identified during the site selection and evaluation process. This activity also included the consideration of other major development projects in Chicago, including the North Loop and Illinois Center, for possible cogeneration applications at these sites. The objective of this task was to identify the most promising sites for further detailed implementation studies to be conducted during Phase II of the UIICSA.

Publications

A primary objective of the UIICSA is the transfer of information concerning the goals of the project and the findings described in this report to persons and institutions that would be involved in developing cogeneration in Chicago. In addition to monthly progress reports and technical memoranda distributed to project monitors and participants, the following publications and educational materials were prepared:

Brochure:

Opportunities for Industrial Cogeneration in Chicago. City of Chicago Department of Planning, September 1981.

Articles:

"Cogeneration: An Innovative Response to Industrial Energy Needs," Chicagoland Development. Chicago Association of Commerce and Industry, August 1981.

"Cogeneration," Illinois Issues, December 1981.

"Thermal-Economic Analysis of Heat-Matched Industrial Cogeneration Systems," Energy, The International Journal. February 1982.

"Cogenerated Energy Recovery From Modular Refuse Incinerators," Journal of Heat Recovery Systems, 1982.

Seminar Booklet:

Opportunities for Cogeneration in Chicago, City of Chicago Department of Planning, November 1981, revised March 1982 and July 1982.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix 2.1

COGENERATION SEMINARS and ENERGY USE SURVEY

Presentations/Seminars

The overall aim of the cogeneration study is to measure the potential for cogeneration in Chicago and to foster the development of viable projects. The development of cogeneration requires cooperation and participation from the city's various sectors including the business community, financial institutions, developers, the local utilities and public agencies. Toward this end, the City of Chicago and other project participants conducted a number of cogeneration presentations and seminars. These forums provided an opportunity to inform the various groups who may become involved in a cogeneration project of the benefits associated with this technology.

The first cogeneration seminar was held on May 21, 1981 for members of the Chicago Association of Commerce and Industry (CACI) Energy, Commerce and Industry Committees (Attachment 1). Participants included representatives from Peoples Gas, Inland Steel, Lester B. Knight and Associates, Sargent and Lundy Engineers, the Chicago Association of Neighborhood Development Organizations and the Chicago Economic Development Commission. As a follow-up to these presentations, project researchers prepared an article entitled "Cogeneration An Innovative Response to Industrial Energy Needs," which was published in CACI's monthly publication, Chicagoland Development (August 1981). In addition, the City of Chicago participated in a CACI conference

entitled "Chicago Area Industries-Past...Present...and Future," which was held on October 28, 1981 (Attachment 2)... Participants in the Conference included representatives of the Illinois Department of Commerce and Community Affairs, the City of Chicago Economic Development Commission, the Illinois Institute of Tehnology and Argonne National Laboratory.

The first cogeneration user seminar was held for local developers on November 4, 1981 (Attachment 3). Presentations at this seminar focused on the potential for incorporating central energy facilities in large commercial developments in Chicago. The seminar was attended by 11 major Chicago developers, and several expressed interest in installing cogeneration systems.

The second user seminar was held on March 11, 1982 at the Midland Hotel in downtown Chicago (Attachment 4). Invitations were sent to approximately 200 Chicago area industrial managers, commercial developers, investment bankers and other interested parties. Seminar presentations included those by Alfred Ronzoni, who installed a cogeneration facility at his New York plant, and Tom Casten, President of Cogeneration Development Corporation, who discussed his experiences with several cogeneration projects across the country. Approximately 50 representatives from the various business sectors attended the seminar.

The third cogeneration user seminar was a joint effort sponsored by the Greater North Pulaski Development Corporation and the City of Chicago Department of Planning (Attachment 5). The seminar was held at Pride Container Corporation and was attended by 25 local manufacturers and other interested parties.

Energy User Survey

In addition to the cogeneration seminars, an effort was made to contact individual energy-intensive firms and facilities through an energy use survey. As a result of the Department of Planning's efforts during Phase I to identify sites and industries suitable for cogeneration in Chicago, 151 potential candidates were selected and contacted. A questionnaire was also developed by project researchers to collect plant-specific energy use data for the Phase II feasibility analyses (Attachment 6). The technology assessment performed at the close of Phase I reduced the 34 sites to 21 on the basis of minimal heat demand. Nine of these sites were considered to have significant potential for cogeneration, and the firms located within these sites were sent the energy use questionnaire. In addition, those industrial firms which expressed interest in the project at the various seminars were also sent questionnaires. A combined total of 81 firms and facilities from these two groups were included in the user survey.

Following the mailing of the questionnaire, project researchers contacted the select companies by telephone to solicit their participation in the cogeneration study. For those interested, site visits were conducted to allow project researchers the opportunity to meet with the owners and plant engineers and to obtain the information needed to conduct detailed feasibility studies. To increase participation in the study, project researchers identified additional facilities other

than those listed in the Phase I industrial survey at those sites felt to have the greatest cogeneration potential. This search involved the analysis of Sandborn maps, Chicago Department of Planning structure maps, aerial photographs and reference to the 1983 Chicago Illinois Manufacturer's Directory. As a result of this process, individual site visits were made to 17 companies (Table 1). The energy use questionnaire was completed by 18 industrial companies and one hospital/medical complex. Four additional companies provided general energy use data, but their overall energy demand was too small to be considered for a central cogeneration facility.

Among the companies participating in the survey, over half are in the food processing industry (Table 2). The largest energy user participating in the survey is Republic Steel. Three-fourths of the facilities included in the survey operate 24 hours per day during the week. Several of the respondents indicated that they would be replacing boilers or expanding their boiler capacities in the near future. Almost all of the respondents indicated they would consider connecting with a central thermal supply system. Major concerns of the respondents related to the financing, ownership and reliability of cogeneration facilities. Respondents also expressed concern about the dependability of on-site backup equipment. Overall, the respondents were cooperative and very interested in learning more about cogeneration and alternative fuels as a means of reducing their energy costs.

Table 1

Facility	Sent 3/82 Seminar Invitation	Attended Seminar	Sent Question- naire	Answered Question- naire	Visited Site
<hr/>					
Site 1:					
Diamond Shamrock	x		x	x	x
Katalco Corp.	x		x	x	x
Sweetheart Cup Corp.	x		x	x	x
Tootsie Roll Ind.	x		x	x	x
Site 2:					
H. Field & Sons Co.	x				
Burbop Paper Co.	x				
Container Corp. of North America	x				
Druth Packaging Co.	x				
Nick Buecher & Sons	x		x		
Site 3:					
University of Ill. Hospital	x		x		
Univ. Health Science/ Chgo. Medical School	x		x		
Ill. Psychiatric Inst.	x				
Rush Presbyterian - St. Lukes Med. Ctr.	x		x	x	
Cook County Hospital	x		x		
Creiger Vocational HS	x		x		
Holy Trinity School	x		x		
Site 4:					
Vienna Sausage Mfg.	x		x	x	x
SCM Corporation	x		x		
Chas Charlotte, Inc.	x		x		
The Pillsbury Co.	x		x		
The Southland Corp.	x		x		
A.E. Staley Mfg.	x		x		
Terrace Paper Co.	x		x		
Stewart Warner Corp.			x		
Tyler & Hippach Glass			x		
Chemical Systems Inc.			x		
Homaco, Inc.			x		
Kinder Plastics			x		
DuPont Demours & Co.			x		
CFS Continental			x		
Arrow Plastics Mfg.			x		
<hr/>					
Total	23		26	6	5

Table 1 Continued

Facility	Sent 3/82 Seminar Invitation	Attended Seminar	Sent Question- naire	Answered Question- naire	Visited Site
Site 5:					
Leaf Confectionery Inc.	x				
Able Moulded Products	x				
Ward-Johnson Schutter Candy Co.	x				
Flex-O-Glass	x				
Playskool, Inc		x	x		
AMCO Corporation			x		
Chromium Industries			x		
St. Anne's Hospital			x		
Site 6:					
Augustana Hospital/Health Care Center	x				
Grant Hospital	x				
Site 7:					
Liquid Air Corp. of North America	x				
General Mills, Inc.	x	x	x	x	x
Globe Industries			x		
PVS Chemicals	x				
Site 8:					
Pismark Hotel	x				
State of Ill. Bldg.	x				
State-Madison Bldg.	x				
Site 9:					
General Foods Corp.	x				
Coca Cola Bottling Co.	x				
Site 10:					
Sherwin Williams	x		x		
Production Controls	x		x		
Black Products	x		x		
Site 11:					
University of Chicago	x				
Chicago Theological Seminary Bldg.	x				
Total	19	2	9	1	1

Table 1 Continued

Facility	Sent 3/82 Seminar Invitation	Attended Seminar	Sent Question- naire	Answered Question- naire	Visited Site
Site 12:					
R.R. Donnelley & Sons	x				
Michael Reese Hospital	x				
Site 13:					
Proctor & Gamble Mfg.	x		x	x	
United Container Corp.	x				
Site 14:					
W.F. Hall Printing Co.	x	x			
Werber Co.	x				
Site 15:					
Northwestern University Medical School	x				
Site 16:					
Hunt-Wesson Foods	x	x	x	x	x
Royal Dutch Meat Co.	x		x		
Central Can Corp.	x		x		
The Abex Corp.			x		
The Elitz Corp.			x		
Pest Foods	x	x	x		
CPC International, Inc.	x				
Site 17:					
Union Chemical Co.			x		
Continental Can Inc.	x		x		
Griffith Labs USA	x	x	x	x	x
White Stokes Co.	x		x	x	x
Wm. Wrigley Co.	x		x		
Anderson Specialty Mfg.	x		x	*	x
Bienenfeld Glass Corp.	x				
Realemon Foods-Beverages			x	*	
Shulze & Burch Biscuit			x		
Paragon Paper Box			x		
Master Paper Box			x		
Schwab Paper Products			x		
Continental Group, Inc.			x		
National Can Corp.			x		
Berkshire Foods			x		
Hysan Corp.			x		
Continental Envelope Corp.			x		
Total	18	4	23	4	4

* Supplied general energy data.

Table 1 Continued

Facility	Sent 3/82 Seminar Invitation	Attended Seminar	Sent Question- naire	Answered Question- naire	Visited Site
Site 17 Continued:					
Wiremasters Inc.			x		
UP-Way Boning Inc.			x		
Glenmark			x		
Jas Calavetti Meats			x		
Bo Packing Co.			x		
Site 18:					
Biederman Paper Box	x		x	*	
Northwest Cone	x		x	x	x
Sweetheart Cup Corp.			x	x	x
Site 19:					
Apollo Packing Co.	x				
The Drackett Co.	x				
Burton Auto Springs	x				
Midwest Film Corp.	x				
Site 21:					
U.S. Steel Works	x	x			
Site 22:					
Interlake Inc.	x		x		
Republic Steel Co.	x	x	x	x	x
Ford Motor Co.	x	x	x		
Great Lakes Carbon			x		
Cargill, Inc.	x	x	x	x	x
Site 24:					
Ingersoll Products	x		x	x	x
International Harvester	x				
Site 25:					
Gauche Food Products	x		x		
General Mills Corp.	x				
Nabisco Inc.	x		x		
Total	16	4	16	5	5

* Supplied General Energy Data

Table 1 Continued

Facility	Sent 3/82 Seminar Invitation	Attended Seminar	Sent Question- naire	Answered Question- naire	Visited Site
Site 26:					
Cameo Container Corp.	x		x		
Jernberg Forgings Co.	x		x		
Lewis Screw Co.	x		x		
Edsal Mfg.	x		x		
Darling & Delaware			x	x	x
Site 27:					
Amforge-Rockwell Intl.	x	x			
Calumet Heat Treating	x				
Heat Treat Corp. of N. America	x				
Modern Steel Treating	x				
Libby, McNeill & Libby			x	x	x
Site 28:					
Elizabeth St. Foundry	x				
American Can Co.	x				
Site 29:					
Lissner Corp.	x				
Site 30:					
Central Die Casting	x				
Dreeblan Paint Supply	x				
Royal Crown Bottling	x				
National Can Corp.	x				
Swift and Co.	x				
W. Argo Chemical Co.	x				
Republic Food Products	x				
Dresser Industries	x				
Tom Tom Tamales Mfg.	x				
Labels Unlimited	x				
Cherry Meat Packers	x				
Foell Packing Co.	x				
Stromberg Allen Co.	x				
Graham Paint & Varnish	x				
F & F Laboratories	x				
Bradshaw-Praeger & Co.	x				
Total	27	1	6	2	2

Table 1 Continued

Facility	Sent 3/82 Seminar Invitation	Attended Seminar	Sent Question- naire	Answered Question- naire	Visited Site
<hr/>					
Site 31:					
Lewis Plastics	x				
Pride Container Corp.		x	x		
Stewarts Private Blend	x				
Artz T.L. Foundry	x				
Charles Larson & Sons	x				
Litton, Inc.	x				
Si-Lite Corp.	x				
Uniroyal Inc.	x				
Site 32:					
Connelly G.P.M. Inc.	x				
Midland Metal Treating	x				
Thermo Met Inc.	x				
County Criminal Courts	x				
Municipal Contagious Disease Hospital	x				
<hr/>					
Total	12	1	1		
Total of All Facilities	116	12	81	18	17

Table 2

Type of Facility	Number
Food and Kindred Products	10
Chemicals and Allied Products	3
Paper and Allied Products	2
Steel Manufacturing	1
Machinery Products	1
Hospital/Medical Center	1
Total	18

CITY OF CHICAGO
DEPARTMENT OF PLANNING

Presentation
before the

Chicago Association of Commerce & Industry
May 21, 1981

"INDUSTRIAL COGENERATION SYSTEMS ANALYSIS"

AGENDA

- I. INTRODUCTION: Al Thomas, Chicago Association of Commerce & Industry
- II. PROJECT OVERVIEW: Albert H. Baugher, Assistant Commissioner, Chicago Department of Planning
- III. SELECTING AND EVALUATING SITES FOR INDUSTRIAL COGENERATION: Patricia Gallagher, City Planner, Chicago Department of Planning
- IV. TECHNOLOGY ASSESSMENT: Dr. Robert W. Porter, Professor of Mechanical Engineering, Illinois Institute of Technology
- V. INSTITUTIONAL FACTORS: Patricia Gallagher/Albert Baugher
- VI. OPPORTUNITIES FOR CHICAGO INDUSTRY/ROLE OF THE CITY: Albert H. Baugher

Seminār, Wednesday, October 28, 1981

Chicago Area Industries — Past ... Present ... & Future

Palmer House — Adams Room

9:00 a.m. to 3:30 p.m., Registration 8:30 a.m.

Sponsored by Chicago Association of Commerce
and IndustryROUTE TO:

- Status of Chicago Area as a Center for Industry & Economic Development
- Growth Industries & Industries with Growth Potential
- Advancing Technology & Improving Productivity
- Plant & Office Location Trends
- Available Services & Assistance for Development & Retention of Industry in this Area

In spite of national trends indicating increased movement away from the Northeast and Midwest, the Chicago area has continued to thrive as a manufacturing center. Although we are experiencing a declining share of U.S. manufacturing shipments, the Chicago area continues to thrive despite all the adverse arguments against industrial expansion here: cold weather, high unionization, declining population growth and unemployment and workmen's compensation penalties.

The picture is changing however. We still must deal with inflation and perhaps new recession tendencies. Less money will be available for economic development from government sources and long-term rates for development financing are expected to remain high.

In spite of this - or perhaps because of it - there are new programs that suggest increased local and private initiative and new areas to explore with public/private ventures. Many of such programs suggest continuing development opportunities and a promising future for the Chicago area. We invite you to review these programs and outlook perspectives and judge for yourselves.

Speakers & Topics Include:

8:30 a.m. Registration & Coffee

8:45 a.m. Introduction & Welcome - Martin L. Black, Manager, Processing Markets,
Peoples Gas Light & Coke Company (CAI Chairman of Industrial Development)8:50 a.m. COMPARATIVE STRENGTH OF METROPOLITAN CHICAGO AS A CENTER
FOR INDUSTRY & ECONOMIC DEVELOPMENT
John Coulter, Director of Business Development, Chicago Assn. of Commerce & Industry (Continued)

9:00 a.m. Panel: CHICAGO AREA GROWTH INDUSTRIES
& INDUSTRIES WITH GROWTH POTENTIAL

Thomas O'Neil (Moderator)
President & Chief Operating Officer, Corp. Group
Lester B. Kniah & Associates, Inc.

Charles C. Sklavanitis, Executive Director
Chicago Economic Development Commission

Dean F. Whittaker, Manager
Office of Development & Retention
Illinois Dept. of Commerce & Community Affairs

Romalda R. Lopat, Director of Programs
Illinois-Indiana Bi-State Commission

10:30 a.m. Coffee Break

10:40 a.m. Panel: CHICAGO AREA PROGRAMS FOR
ADVANCING TECHNOLOGY & IMPROVING
PRODUCTIVITY

Harry B. Johnson (Moderator)
Principal & Senior Management Consultant
A. T. Kearney, Inc.

Dr. Keith E. McKee, Director of Research
IIT Research Institute

Dr. Richard A. Carrigan, Asst. Head of Research
Div. & Technical Rep. of Industrial Assoc. Program
Fermi National Accelerator Laboratory

A. B. Krieglunas, Asst. to Director of O.P.A.
Argonne National Laboratory

Max Robinette, Sr. Vice Pres. & Area Director
Hamilton/Avnet Electronics

12:30 p.m. Lunch & Cash Bar

1:15 p.m. Luncheon Program

PLANT & OFFICE LOCATION TRENDS
AND OUTLOOK FOR THE FUTURE

Robert Ady, Senior Vice President
The Fantus Company

2:00 p.m. Panel: AREA PROGRAMS FOR THE ATTRACTION
to & RETENTION OF INDUSTRY

3:30 p.m.

J. John Stephens (Moderator)
Coordinator for Economic Development
Commonwealth Edison Company

John Coffey, Assistant Executive Director
Chicago Economic Development Commission

Albert H. Baugher, Assistant Commissioner
Chicago Department of Planning

Richard D. Durkin, Manager
Chicago Office of Development & Retention
Illinois Dept. of Commerce & Community Affairs

Joseph H. Abel, Director
DuPage County Dev. Dept., Planning Division

Make your reservations early. Please call 786-0111, Ext. 225. CACI Members,
\$35.00 per person; Non-Members, \$40.00 per person. There will be a \$5.00
additional charge for late registration or payment at the door. Program includes
luncheon, literature, handouts and exhibits.

CACIF

Commercial & Industrial Development Division
Chicago Association of Commerce and Industry
130 South Michigan Avenue, Chicago, Illinois 60603

Please make _____ reservations for CHICAGO AREA INDUSTRIES
seminar, Wednesday, October 28, 1981. Check for _____ enclosed.

NAME(S) _____

FIRM _____ PHONE _____

ADDRESS _____

Attachment 3

CITY OF CHICAGO
DEPARTMENT OF PLANNING

Cogeneration Seminar
November 4, 1981

Agenda

10:15	Opening Remarks	Martin R. Murphy
10:20	Cogeneration Slide Presentation	
10:30	Technical Concepts	Robert W. Porter
10:45	Incentive Programs	Ross D. Ain
11:15	Detailed Case Analyses	Ross D. Ain/ Robert W. Porter
11:30	Discussion	
11:45	Closing Remarks	Alber H. Baugher

CITY OF CHICAGO
DEPARTMENT OF PLANNING

Developers' Seminar
November 4, 1981

PRESENT

1. Dan O'Neill
Arthur Rubloff & Co.
2. Ben Svoboda
Lester B. Knight & Asso.
3. Fred Corban
Inland Steel
4. Larry Greco
Flcetwood Realty
5. Paul Dillon
Mid-America Appraisal and
Research Corp.
6. Robert Lapen
The Seraco Group
7. Dan Shannon
Dan Shannon & Company
8. Clif Martin
Fifield, Palmer & Company
9. Don Samuelson
Metropolitan Structures
10. Eugene Ross
Berger Realty
11. Leonard Rose
Industrial Development Co.

ABSENT

Eugene Callahan
The Callahan Company

Jack Quigley
Continental Illinois
National Bank

Paul Zeller
The John Buck Company

Charles Sklavanitis
City of Chicago
Economic Development
Commission

CITY OF CHICAGO
DEPARTMENT OF PLANNING

COGENERATION SEMINAR

THURSDAY, MARCH 11, 1982

10:00 A.M. — NOON

HOLABIRD ROOM, MIDLAND HOTEL

172 W. ADAMS

CHICAGO, ILLINOIS

AGENDA

10:00 A.M.	Registration	Martin R. Murphy
	Opening Remarks	
	Cogeneration Video Presentation	
	Technical Concepts	Robert W. Porter/ Alfred Ronzoni
	. Basic Equipment	
	. Example	
	Incentive Programs	Ross D. Ain
	Detailed Case Analyses	Ross D. Ain/ Robert W. Porter
	Industrial Application	
	Commercial Application	
	Comments/Discussion	Thomas Casten
NOON	Closing Remarks	Albert H. Baugher

Useful information will be presented on how money can be saved and profits increased using this energy technology system. We encourage you to attend.

CITY OF CHICAGO
DEPARTMENT OF PLANNING/
ILLINOIS INSTITUTE OF TECHNOLOGY

COGENERATION SEMINAR
March 11, 1982

List of Participants

Joseph Agosta
Commonwealth Edison Co.

Suhail al Chalabi
City of Chicago
Office of the Mayor

Mahendra Amin
Best Foods

Jon Anda
Continental Bank

Bradley C. Barrett
First National Bank
of Chicago

Robert Bauer
U.S. Dept. of Energy

H.A. Bonigut
Commonwealth Edison Co.

W.W. Brandfon
Sargent & Lundy

Rollie Brandon
Cosentini & Associates

Walter Bridges
U.S. Steel - South Works

James Castle
City of Chicago
Dept. of Streets & Sanitation

Zahid Chaudary
Ill. Institute of Technology

Thomas DePre
Warburg Paribes Becker Inc.

Paul Dillon
Mid-America Appraisal
& Research Corp.

Robert Dunne
U.S. Dept. of Energy

Darryl Erickson
Griffith Labs. USA

Gail Ettinger
Evanston, Illinois

Jack Faddis
U.S. Dept. of Energy

Gary Fowler
Energy Resources Center
University of Illinois
at Chicago

Kitty Freidheim
City of Chicago
Dept. of Planning

Homer Gardner
Amforge, Inc.

Carl A. Groesbeck
Peoples Gas Light and
Coke Company

Paul Helmstetter
Ford Motor Company

William Herman
State of Illinois
Governor's Office of
Consumer Services

Robert Hockhalter
General Mills

Michael Horn
Illinois Housing
Development Authority

Alan Jennessen
Cargill Inc.

Paul Karas
Santa Fe Industries

Lawrence Kostrzewa
Gas Research Institute

Les Lausch
Ford Motor Company

Greg Lofstedt
Cargill Inc.

Ronald J. Lutha
U.S. Dept. of Energy

Alister MacDonald
W.F. Hall Company

Thomas J. Marciniak
Fauske and Associates

K. Mastanaiah
Ill. Institute of
Technology

Michael Murphy
Reedy Industries

Peter Penner
State of Illinois
Governor's Office

Dado Puga
Hunt-Wesson Foods

H.A. Razzack
Ill. Institute of Technology

John Robles
City of Chicago
Dept. of Streets & Sanitation

Tripta Sarin
Hunt-Wesson Foods

Robert Syrup
General Mills

William Trebs
Peoples Gas Light
& Coke Company

William Udovich
Republic Steel

George Vadervoort
Sargent & Lundy

Donald Vilchuck
U.S. Steel

Janet Wolf
City of Chicago
Dept. of Economic
Development

City of Chicago
Dept. of Planning
Cogeneration Project Staff:

Albert H. Baugher
Leslie A. Savage
Patricia Gallagher
Anita Salazar

Project Consultants:

Robert W. Porter
Illinois Institute of
Technology

Ross D. Ain
Van Ness, Feldman, Sutcliffe,
Curtis and Levenberg

THE GREATER NORTH PULASKI DEVELOPMENT CORPORATION
AND THE CITY OF CHICAGO DEPARTMENT OF PLANNING

COGENERATION SEMINAR

THURSDAY, JULY 22, 1982

10:30 A.M. — NOON

PRIDE CONTAINER CORPORATION
4545 WEST PALMER
CHICAGO, ILLINOIS

A G E N D A

10:30 A.M.

OPENING REMARKS

JOHN HOLMBERG/
LESLIE SAVAGE

COGENERATION VIDEO
PRESENTATION

TECHNICAL CONCEPTS

ROBERT W. PORTER

INCENTIVE PROGRAMS

ROSS D. AIN

DETAILED CASE STUDIES

ROBERT W. PORTER

▪ COMPARATIVE INDUSTRIAL
APPLICATION

▪ REFUSE-BURNING INCINERATION
APPLICATION

COMMENTS/DISCUSSION

NOON

CLOSING REMARKS

LESLIE SAVAGE/
JOHN HOLMBERG

THE GREATER NORTH PULASKI DEVELOPMENT CORPORATION
AND THE CITY OF CHICAGO DEPARTMENT OF PLANNING

COGENERATION SEMINAR

THURSDAY, JULY 22. 1982

ATTENDANCE SHEET

<u>NAME</u>	<u>FIRM/ORGANIZATION</u>
James Lemonides	Greater North Pulaski Dev. Corp. 4054 W. North Ave.
Bruce Dillenbech	Greater North Pulaski Dev. Corp. 4054 W. North Ave.
Linda Simon-Price	Greater North Pulaski Dev. Corp. 4054 W. North Ave.
Martin L. Black	Peoples Gas Light & Coke Company 122 S. Michigan Ave.
Confesor Rosa	Pioneer Bank & Trust Company 4000 W. North Ave.
Wayne Penn	Pioneer Bank & Trust Company 4000 W. North Ave.
John Holmberg	Chambers Gasket 4701 W. Rice
John McAuly	Peoples Gas Light & Coke Company 122 S. Michigan Ave.
Edward S. Hanzlik	Playskool Inc. 4545 W. Augusta
Laura Skup	Potenital Energy 3757 W. Campbell
Manhar Soni	Acme Frame Products 2622 N. Pulaski
Jean Daskais	Medill News Service 2 Illinois Center
James A. Easter	Airway Pest Control Company 2232 N. California
Jean Pogge	Woodstock Institute 410 N. Michigan Avenue

7/22/82 SEMINAR ATTENDANCE SHEET (continued)

NAME	FIRM/ORGANIZATION
Charles McLaughlan	Arrowhead Heating & Cooling 3849 W. Cortland
Kathy Tholin	Center for Neighborhood Tech. 570 W. Randolph
Daniel Becker	Center for Neighborhood Tech. 570 W. Randolph
Tom Jaack	Clayton Manufacturing 9668 Allen Ave., Rosemont, IL
Jim Thompson	Clayton Manufacturing 9668 Allen Ave., Rosemont, IL
Richard Sharfstein	Pride Container 4545 W. Palmer
Bob Verhunce	Pride Container 4545 W. Palmer
Don Vernier	Pride Container 4545 W. Palmer

CITY OF CHICAGO
DEPARTMENT OF PLANNING

Leslie Savage
Patricia Gallagher
Anita Salazar
Laura Metro

Consultants:
Dr. Robert W. Porter
Ross D. Ain

INDUSTRIAL COGENERATION SURVEY

As part of a study sponsored by the U.S. Department of Energy, the City of Chicago and the Illinois Institute of Technology are gathering energy demand and use data to determine the magnitude of cogeneration potential in Chicago. We ask that you take the time to complete the following questionnaire and return it in the self-addressed stamped envelope enclosed.

A copy of the data used and our evaluation of your facility will be furnished to you in return for your assistance. Your help in this study may be of considerable value in the effort to reduce energy costs in Chicago.

If you have any questions regarding the questionnaire or need additional information, please call the City of Chicago Department of Planning at (312) 744 - 3025.

City of Chicago

Jane M. Byrne, Mayor

Martin R. Murphy
Commissioner
Department of Planning

Name: _____

Firm: _____

Address: _____

Plant Address: _____

Telephone: _____

1. What types of products are manufactured at your plant? _____

2 In what ways does your plant use heat in its processes? _____

washing / sanitary _____ pastuerizing _____ cooking _____

distillation _____ blanching _____ process hot water _____

liquids heating _____ baking _____ drying _____

melting _____ smelting _____ sintering _____

heat treating _____ absorption A/C _____ other (specify) _____

3. How many 8-hour shifts per day on weekdays? _____ Weekends _____

4. Would you consider interconnecting with a central thermal supply system? If not , why?

5. Remaining life of plant _____ yrs.

6. Summarize major equipment changes anticipated _____

7. Any restrictions on natural gas, oil or coal? _____

8. Minimum acceptable rate of return or investment ? (1)
(Specify after or before taxes and whether effective rate or real rate relative to
general inflation.)

9. Can you use tax credits and depreciation tax deductions at this time and in the future ?

10. Is your plant structure usable for a retrofit facility ?

11. Are other plant items reusable ? _____

12. Is continuous high - level plant operation essential or can you accommodate reduced levels to
save the cost of backup equipment ?

(1) Usually the discount rate applied in engineering studies considering risk involved.

13. ELECTRICAL LOAD DATA

Monthly loads :	Peak kWh(e)	Off - Peak kWh(e)	Demand kW (e)
January	_____	_____	_____
February	_____	_____	_____
March	_____	_____	_____
April	_____	_____	_____
May	_____	_____	_____
June	_____	_____	_____
July	_____	_____	_____
August	_____	_____	_____
September	_____	_____	_____
October	_____	_____	_____
November	_____	_____	_____
December	_____	_____	_____

14. THERMAL LOAD DATA⁽¹⁾

a. Type of Thermal Load:

Steam at _____ psig/F

Hot Water at _____ F

Direct Heat at _____ F

_____ B/hr. (2)

_____ ft³ /hr.

b. Peak Thermal Load:

Steam at _____ lbm/hr.

Hot water at _____ lbm/hr.

Direct Heat at _____ lbm/hr.

_____ B/hr (2)

_____ ft³ /hr.

1) Use multiple pages for multiple uses if necessary.

2) Specify reference datum (ambient temperature, etc.)

and whether gross or net value: _____

c. Monthly Energy Use:

	<u>HV¹</u>	<u>Thermal Efficiency²</u>
☐ Natural Gas (therms/mo)	_____	_____
☐ Oil (gal/mo)	_____	_____
☐ Coal (tons/mo)	_____	_____
☐ _____	_____	_____

January	_____
February	_____
March	_____
April	_____
May	_____
June	_____
July	_____
August	_____
September	_____
October	_____
November	_____
December	_____

1) Heating value in BTU/unit. Specify higher heating value (H) or lower heating value (L) if known.

2) Overall conversion efficiency between fuel HV and thermal product (steam, etc.) in %.

15. ELECTRICITY DEMAND PROFILE (Optional)

Year Reported: _____

	TYPICAL WEEK daily averages, as fraction of highest day of week	TYPICAL WEEK DAY hourly averages, as fraction of peak hour	TYPICAL WEEKEND DAY hourly averages, as fraction of peak hour
WINTER Dec, Jan, Feb			
SPRING Mar, Apr, May			
SUMMER Jun, Jul, Aug			
FALL Sep, Oct, Nov			

16. THERMAL DEMAND PROFILE (Optional)

Year Reported: _____

	TYPICAL WEEK daily averages, as fraction of highest day of week	TYPICAL WEEK DAY hourly averages, as fraction of peak hour	TYPICAL WEEKEND DAY hourly averages, as fraction of peak hour
WINTER Dec, Jan, Feb			
SPRING Mar, Apr, May			
SUMMER Jun, Jul, Aug			
FALL Sep, Oct, Nov			

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix 3.1

Air Pollution Emission Calculations

Incineration Rates:

150 Tons/Day/Module x 2000 Lbs./Ton x 1/24 Day/Hr. =
12,500 Lbs./Hr.

150 Tons/Day/Module x 365 Days/Yr. x 0.85 = 46,530 Tons/Yr.

Dry Flue Gas Flow Rate:

12,500 Lbs. Hr. x 4400 BTU/Lb. = 55,000,000 BTU/Hr.

55,000 BTU/HR. x 0.85 = 46,000,000 BTU/Hr.

7.5 x 55,000,000/60/10,000 = 687 Lbs./Min.
(Stoichiometric)

687 Lbs./Min./0.079 Lb./SCF = 8702 SCF
(Stoichiometric)

8702 SCF/Min. x 1.5 = 13,054 SCF at 50% xs air.
(Full incinerator charge rate)

Particulate Emission Rates:

13,054 SCF/Min. x 60 Min./Hr. x 365 Days/Yr. x 24 Hrs./
Day x 0.85 x 0.08 Grains/SCF x 1/2000 Ton/Lb./7000 Grains/Lb. =
33 Tons/Yr.

(This is the emission rate based on the allowable limit of 0.08
Grains/SCF at 50% xs air.)

33 Tons/Yr. x (0.03/0.08) = 12.4 Tons/Yr.

(This is the emission rate that the incinerator designer proposes
as his warrantee maximum, which has been achieved by reduction to
an average emission concentration of 0.03 Grains/SCF at 50% xs
air. This is with the designer's "state-of-art" particulate
control device.)

Oxides of Sulfur Emission Rates:

(The incinerator designer uses an analyses showing 0.0012 Sulfur in refuse, but adjusts for 20% water content in the analyses and 45% water content in municipal refuse.)

$$(0.20 + 0.55)/(0.45 + 0.55) \times 46,530 \text{ Tons/Yr.} \times 0.0012 = 42 \text{ Tons Sulfur/Yr. (in refuse)}$$

If all the Sulfur charged burns to Sulfur Dioxide, with change in weight due to oxidation:

$$64/32 \times 42 \text{ Tons/Yr.} = 84 \text{ Tons/Yr.} \\ \text{(Expressed as Sulfur Dioxide)}$$

(This emission will be reduced if we consider that some of the Sulfur will remain in the residue after incineration)

Carbon Monoxide Emission Rate:

$$(10 \text{ PPM}/1,000,000) \times 13,054 \text{ SCF/Min.} \times 60 \text{ Min./Hr.} \times 24 \text{ Hrs./Day} \\ \times 365 \text{ Days/Yr.} \times 0.85/359 \text{ SCF/Mole} \times 28 \text{ Lb./Mole}/2000 \text{ Lbs. Ton} = 2.27 \text{ Tons/Yr.}$$

Oxides of Nitrogen (Expressed as Nitrogen Oxide) Emission Rate:

$$(35 \text{ PPM}/1,000,000) \times 13,054 \text{ SCF/Min.} \times 60 \text{ Min./Hr.} \times 24 \text{ Hrs./Day} \\ \times 365 \text{ Hrs./Day} \times 0.85/359 \text{ SCF/Mole} \times 30 \text{ Lb./Mole}/2000 \text{ Lbs./Ton} = 8.5 \text{ Tons/Yr.}$$

Factors, Values and References:

1. Incineration Rate Per Module: 150 Tons/Yr.
2. Module Time-In Service Factor: 0.85
3. Heat Value of Refuse: 4400 BTU/Lb.
4. Gas Density (Air and Flue Gases): 0.079 Lb./SCF
5. Allowable Particulate Emission Concentration: 0.08 Grains/SCF
6. System Warrantee Particulate Emission Concentration: 0.03 Grains/SCF
7. Sulfur Content of Refuse: 0.12 of 1%
8. Water Content of Refuse Analysed: 20%
9. Water Content of Refuse Incinerated: 45%
10. Molecular Weight of Sulfur dioxide: 64 Lb.

11. Atomic Weight of Sulfur: 32 Lb.
12. Sulfur or Sulfur compounds in Residue: Negligible
13. Carbon Monoxide Emission concentration: 10 PPM by Volume
14. Molecular Weight of Carbon Monoxide: 28 Lb.
15. Volume of one Lb. Mole of Gases: 359 CFM
16. Nitrogen Oxide Emissions Concentration: 35 PPM by Volume
17. Molecular Weight of Nitrogen Dioxide: 30 Lb.
18. References:
 - a) Item 5 is per Ill. APC Regulations, Rule 203(e)(2). This limit is required to be applied in Chicago due to constitutional home rule provisions, despite Chapter 17-2.4(5) of the Municipal Code limit 0.20 Grain/SCF.
 - b) Item 7 is from several publications, one being Pollution Engineering Handbook, Chemisoff and Young, 1st edition, Page 745.
 - c) Item 8 (Same as Item 7).
 - d) Item 9 is generally acceptable, but was derived from Table 2 statement "Less 25% Water," and is, therefore, designer's value.
 - e) For purposes of simplifying calculations without substantively affecting results:
 - 1) Nitrogen in Refuse: Negligible except as found and expressed as Nitrogen Oxide in emissions.
 - 2) Hydrogen in Analyses of Refuse: Negligible
 - 3) Hydrogen Oxidized in Incinerator: Negligible
 - 4) Simplified Stoichiometric Formula from reference in (b), Page 714.
 - f) Items 13 and 16 from tests performed on previous systems by designer.

Prepared by: Walter Linna, Environmental Engineer,
Chicago Department of Consumer Services,
November 1983 with the assistance of John
Basic, Sr., President of Basic Environmental
Engineering Company.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix 4.1

REVENUE BOND FINANCING STRUCTURE

The following steps are typically taken in a revenue bond financing structure involving a full-service contractor (Figure I):

1. The municipality issues bonds to investors (bondholders); the proceeds of the bond sale are paid to a trustee or to the public entity.
2. The municipality enters into an agreement with a trustee and assigns the revenues to be collected from the project to the trustee as security for payment of the bonds, along with a commitment to provide additional funds if necessary, such as proceeds of a further bond issue, special assessments of increased user fees, etc. The trustee in turn administers and dispurses the bond proceeds pays the interest on and eventually retires the bonds.
3. The municipality enters into a contract for construction of the facility; on behalf of the municipality the trustee uses the proceeds from the bond sale to pay for construction of the facility. The municipality also enters into a contract for operation of the facility by the full-service contractor who constructed the facility and agrees to pay that contractor a specified annual operating fee which will be adjusted annually based on the rate of change in a mutually agreed-upon external escalator.
4. In order to secure the revenue streams for the facility, prior to or concurrent with the issuance of the bonds, the municipality enters into long-term energy sales contracts as well as long-term contracts for waste supply and the sale of any recovered materials.
5. Revenues from the operation of the facility flow through the indenture trustee to pay interest on and retire the bonds and to pay the contractor's fee for operation of the facility.

FIGURE I: REVENUE BOND FINANCING

Appendix 4.2

THIRD-PARTY TAX LEASE FINANCING STRUCTURE

The various elements of a third-party tax lease structure are as follows (Figure II):

1. A full-service contractor would enter into a lease with the third-party investor/owner of the facility. The lease would have to meet IRS guidelines to enable the third party to obtain tax benefits.
2. The full-service contract could also unconditionally guarantee lease payments.
3. The municipality would issue IDBs for construction of the facility.
4. The third-party investor would provide a direct equity contribution of the funds needed after the bond issuance for the construction of the waste-to-energy facility. In return, the third party would assume the beneficial tax ownership of the facility.
5. The municipality or the third-party investor would enter into a separate contract with the full-service contractor to construct and operate the facility.
6. The right to rent from the lessee to the third-party investor and the obligation to make payments on the loan of bond proceeds or use of the facility from the third party to the municipality would all be assigned to a trustee for the bondholders.
7. The agreement between the third-party investor and the municipality would commence at the same time as the true lease between the third-party investor/lessor and the full-service contractor (lessee). Rent from the lessee to the lessor would be sufficient to cover debt service on the bonds. Since the lessor would have assigned its right to receive the lessee's rental payments to the municipality, the rents could be paid directly to the municipality or the trustee for the bondholders.
8. The third-party owner/lessor would claim the tax benefits and also receive any rental payment (i.e., nominal profit) in excess of that required for debt service on the bonds.
9. The lessee/operator may receive an operating fee and a share of the revenues from the project and the municipality may also get a portion of the income from the project.

FIGURE II: TAX LEASING

Appendix 5.1

**CASE STUDY OF REFUSE-FIRED COGENERATION
FOR STOCKYARDS INDUSTRIAL AREA**

Energy Management Memorandum TM-83-2

*Robert W. Porter, P.E.
Professor*

*Hayder Abdul-Razzak
Research Assistant*

*Department of Mechanical Engineering
Illinois Institute of Technology
Chicago, Illinois 60616*

September, 1983

*Topical Report prepared under Subcontract 50391
Chicago Department of Planning
U.S. Department of Energy Grant DE-FG02-80CS40337*

Project Description

The project "Urban Integrated Industrial Cogeneration Systems Analysis" concerns the identification and resolution of institutional, legal and economic issues of cogeneration in the urban environment. It also deals with technical matters particularly including thermal-economic analysis of cogeneration within the context of regulation, financing, optimization and design. The work is applied using a case study approach to cogeneration opportunities identified by a survey of companies and institutions in the City of Chicago performed in cooperation with Commonwealth Edison Company and Peoples Gas Company and as identified by other sources of the Chicago Department of Planning and Illinois Institute of Technology. The project attempts to bring to the attention of the industrial-commercial sector the opportunities and benefits of cogeneration in stimulating economic development through efficient energy utilization.

Table of Contents

	Page
Project Description	182
Summary	183
Introduction	185
Site Considerations	186
Thermal-Economic Analysis	187
Thermal Performance	187
Economic Analysis	187
References	190

Summary

The Stockyards area was analyzed as a case study for cogenerated energy recovery from refuse using modular water-wall mass-burning incinerators. The system would operate at near available capacity, supplying about 56% of the steam requirements of four local industries. The facility would be rated at 300 TPD of refuse processing, 52,400 lbm/hr of steam and 1.5 MW(e) of electricity.

Revenues for the plant would include a tipping fee for refuse processing and income from steam sales. Electricity is best utilized to displace purchases of the users from the local utility, but can also be sold to the local utility according to federal regulations governing cogeneration and small power production from alternative energy. For a proposed 40% leveraged lease and 60% IDB (Industrial Development Bond) financing, a discount can be given to energy users as an incentive to connect and to stimulate economic development in the area. In the case of sales of both steam and electricity to local users, a discount of up to 59% may be applied if no direct incentive is given to refuse tipping. The owner of the facility need make no initial investment but would be subject to obligations for the debt and lease. Should users decide to own the facility, they could attain "recapture" and be able to cover all debt and lease obligations after 12.1 years on a nondiscounted basis, exclusive of discounts for cogenerated energy utilized.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Introduction

During Phase I of the present project, it was determined that the Stockyards area was potentially attractive for a small refuse-fired central cogenerated steam supply (Porter, Dec. 1982). Feasibility was conditional upon the identification of sufficient steam load among existing or new users. Based on this potential and the desire of the City to promote industrial development in the area, a concentrated effort was made to identify and survey industries that would be interested in connecting to the system and which would form the basis for an economic exploitation of the technology.

As a result of this effort, the following companies were found to satisfy the project requirements:

Darling and Company
Griffith Industries USA, Inc.
White-Stokes Co.
Sweetheart Cup Co. (Ashland Plant)

In addition, two parcels of vacant land were identified for future location of new industry.

It is proposed to construct a 300-TPD incinerator which would operate continuously to the extent of available capacity. An average steam output of 41,400 lbm/hr would meet 56% of the steam requirements of the above industries based on 1982 utilization. The average electrical output of 1.2 MW(e) can readily be used by the same companies or sold to Commonwealth Edison Co. under PURPA (Public Utility Regulatory Policies Act of 1978). If these or other companies are able to displace purchases from the local utility, a greater economic incentive exists. However, the project appears viable on either basis.

The above-size plant was chosen in order to maximize economic advantage as reflected by the savings in energy cogenerated as compared with conventional generation. This criterion dictates near full utilization of available steam capacity, in the present case about 98%. While a larger plant benefits from economy of scale, it would be used less during off-peak demand and therefore cannot as effectively amortize its capital cost in terms of a low fixed charge to energy produced. Rather, additional modules can be added in order to increase capacity should further steam demand be developed due to the location of new industries or the expansion of present ones.

The proposed system employs two 150-TPD refuse-incineration boilers generating 625 psig/725°F steam suitable for expansion in topping (back-pressure) steam turbines prior to utilization at 150 psig, making allowances for various losses in the system. The particular system analyzed (Chaudhary and Porter, Dec. 1982) is available from Basic Environmental Engineering Company, Inc. of Glen Ellyn, Illinois. It utilizes an efficient water-wall construction with an articulating grate suitable for mass burning of municipal refuse with minimal preprocessing. Gas cleanup equipment to be supplied with the unit is anticipated to meet environmental requirements.

The present analysis is based on a nominal economic life cycle commencing in 1986 and lasting for 20 years. Experience with incinerators using municipal refuse suggests that longer life cycles are unrealistic. Financing is assumed to involve 60% IDB (Industrial Development Bonds) and 40% leveraged lease, the lease being 80% debt financed with a conventional loan (Van Ness, et al, Nov. 1982). It is believed that this financial arrangement would be attractive to third party investors (other than steam users and the electric utility) because of the internal rate of return on equity investment provided. The steam users may be reluctant to commit capital owing to a desire to use their funds for production. The local electric utility may, or may not, be receptive to financing the venture due to their mixed feelings toward participating in, or discouraging of, cogeneration.

Site Considerations

The site of the proposed incinerator and cogeneration plant is shown in Figure 1. The facility may be located at the presently existing transfer station (formerly Southwest Incinerator) or at any point along the distribution system. Two parcels of vacant land are available if necessary. However, in the analysis which follows, no allowance is made for the cost of land. Instead it is assumed that the City would make available a portion of its transfer station, or that one of the industries, particularly Darling and Company, would contribute the necessary space on a nominal lease basis. In either case, the cost is relatively small in relation to the benefits accrued. At the end of the life cycle, the land would revert back to control of the owner and the arrangement would be renegotiated.

The distribution system involves 12,550 ft each of dual piping for supply (12 inch) and condensate return (3 inch). If it is later determined that the cogenerated electricity can indeed be used to displace purchases, an electrical cable will be co-located.

A number of users in the area were surveyed for steam and electrical usage. It became evident that there was only one major user of steam interested in the proposal, Darling and Company. However, the other users help level the load and justify the piping system which can be utilized as the basis for future expansion.

Monthly steam utilization of the companies is given in Table 1. Table 2 gives weighting coefficients for 12 periods within a month in order to represent the overall load profile. In effect, the steam load is described in terms of four-hour periods. The coefficients of Table 2 give the multiple of average monthly steam load that prevails during the four-hour period of interest.

It became evident that the various users consume substantially more electricity than can be generated by the planned facility. A preliminary review by the ICC (Illinois Commerce Commission) has indicated that cogenerated electricity can be used to offset purchases from the local utility in the case of a user-owned facility. In addition power may be sold so long as the seller does not hold itself out to be a public utility. Nevertheless, this interpretation is controversial and is under review (Teclaw, Aug. 4, 1983).

In order to determine the maximum economic advantage, the cogeneration plant was sized to supply essentially base loading. That is, any larger facility would have to follow a fluctuating load with an attendant increase in unit energy costs due to higher fixed charges. The peak load, during Nov.-Jan. weekdays from 6 p.m. to 6 a.m., is about 122,000 lbm/hr. The minimum load, during May-June weekends from 6 a.m. to 6 p.m. is 31,000 lbm/hr. The annual average is 74,000 lbm/hr. The present system has an available capacity of 41,400 lbm/hr and would meet 56% of the users' combined load, operating at full available capacity 98% of the time.

The site is presumed to have adequate refuse storage space in order to continue refuse burning during periods of non-collection, evenings and weekends. The facility is anticipated to be available for refuse processing with or without steam production 81% of the time, full-load equivalent. That is, the facility could operate on the average as though it were operating at full load 81% of the time.

A substantial part of the advantage of the present site is its proximity to the "centroid" of available refuse. Thus, the facility should contribute positively to the City's overall collection strategy. A larger facility could lead to lesser loading of the Northwest Incinerator during winter months. Alternatively, refuse not presently collected by the City could be tipped at the site. The present small facility is believed to be conservative and should not lead to any adverse impact on collection.

Thermal-Economic Analysis

Thermal Performance

The details of the modular system design are contained in a report by Chaudhary and Porter (Dec. 1982). Performance factors are summarized in Table 3. Most notable are (1) the capacity of the system which determines its initial cost and (2) the average performance of the system which determines its annual cash flows. The annual cash flows include incomes due to steam sales or, equivalently, fuel savings, income due to electricity sales or savings due to displaced purchases, and net income due to tipping fees for processing refuse less costs due to operation and maintenance.

Economic Analysis

All costs in the present study were adjusted to account for general inflation as reflected by the Producer Price Index (Table 4). In particular, projections for the project life cycle (1986-2005) indicate an inflation rate averaging about 6.5%. In the present study it is assumed that all incomes or savings for steam, electricity and refuse processing are adjusted for inflation and real escalation as discussed below. A higher than anticipated inflation rate would result in a devaluation of the income tax deduction due to depreciation, over the first 5-8 years of the project depending on the type of financing. On the other hand, revenues would increase at a rate greater than expenses of debt service and leasing, a favorable effect.

Conversely, lower than expected inflation would increase the value of depreciation. Revenues would be reduced relative to expenses of debt service and leasing. However, lower than anticipated inflation would also probably result in further economic development and an expansion of the facility. Such expansion could be based on then prevailing and projected conditions. These compensating effects tend to protect the project against changes in inflation.

Projections for fuel costs are given in Table 5. In the present project, it is assumed that steam revenue is coupled to the cost of Class 3 natural gas service with a predicted 3% compound annual real escalation rate relative to inflation. The value of steam is computed according to the cost of generation in a natural-gas-fired boiler of 84% efficiency as noted in Table 3. Oil fuels are expected to have similar real escalation rates as for natural gas. In effect, steam revenues are presumed directly adjusted according to the prevailing cost of alternative fuel. The main risk is that fuel costs may drop.

The projected value of cogenerated electricity is given in Table 6. We consider cases of (1) displaced purchases under Rate 6L for less than 10 MW(e) demand and (2) sales to the electric utility under Rider 4. The latter is less favorable and so displacing purchases is the economic choice according to the present data. Present projections reflect a negative real escalation in these prices, associated with expanded nuclear energy utilization of the local utility. However, some sources have predicted positive real escalation of electrical rates. This circumstance would increase the value of the project so long as contractual prices are coupled to utility rates.

A review of the net credit for processing refuse including charges for operation and maintenance (O&M) has indicated that previous estimates (Chaudhary and Porter, Dec. 1982) are essentially correct when adjusted for inflation in the interim. The net credit is \$3.50/ton (processed) in 1983 dollars. This credit includes a tipping fee covering alternative disposal costs and collection savings, less O&M and ash disposal costs:

	1983-\$/ton
Tipping Fee (Income)	
Alternate Disposal	
Transportation	\$6.81
Drop Fee	11.87
Collection Savings	3.56
	<u>\$22.24</u>
O&M, Etc. (Expense)	
Plant	\$18.36
Ash Disposal	0.38
	<u>\$18.74</u>
Net Credit (Income less Expense)	\$3.50

No direct savings has been accrued to the City of Chicago for use of the facility. Indirect savings would include that associated with economic development and conservation of landfill.

The capital cost of the plant including interconnection with the utility but excluding distribution piping and cable is given in Table 7. This cost will be adjusted depending on the disposition of generated electricity. General economic parameters are given in Table 8.

The capital costs, and the values of steam, electricity and refuse processing for the first year of operation (1986) are given in Table 9. Based on simple payback period, displacing purchases of electricity is preferred to sales to the electric utility. However, both modes of operation will be analyzed further because (1) the lower capital cost of sales to the utility due to lesser distribution costs may justify this choice if the cost of capital is great enough and (2) displacing purchases may be discouraged due to regulatory problems, costs of back-up power, marketing strategy of the electric utility, etc.

The proposed financial scheme involves 40% leveraged leasing, by the major equipment manufacturer or other party. The 5-year lease was assumed to be financed itself by 80% debt over 5 years at 18.2% in current year-of-service dollars. The lease payment was computed to provide lessor a 25.3% rate of return on his 20% equity in current year-of-service dollars, after income taxes. Lessor's cash flows are illustrated in Table 10. Lessor recovers his initial investment in 2.2 years before taxes. However, "recapture" including debt obligation does not occur until after 4.7 years. Thus, from the point of view of Lessor, the project must survive essentially five years. After this point, Lessor has no further obligation or benefit related to the venture.

Cash flows for the combined Lessee and Users are given in Table 11. In addition to the 40% lease, 60% of the capital requirements are taken as being financed with an 11.8% 20-year IDB issue. Electrical revenues are taken as the savings due to displaced purchases. As can be seen, positive cash flows occur every year of the project. Thus, it would appear desirable for the Users to put forward the venture at essentially no cost. However, it requires approximately 12.1 years for the positive cash flows to offset the debt and lease obligation (recapture). In the event that the Users choose not to so obligate themselves, an independent Lessee may be sought. Cash flows for Lessee are shown in Table 12 using an interest rate of 25.7% and a present worth of zero. Ordinarily this condition would imply a rate of return on equity of 25.7% after taxes. However, the initial cash flow is positive, an income due to the tax credit. There are three reversals in sign of net annual cash flows over the 20 year life of the project. This circumstance requires the Lessee to be able to re-invest positive cash flows at essentially 25.7% or more rate of return after taxes for the results to be meaningful.

Using the present assumption, Lessee can pass on a 59% discount in the form of reduced steam and electricity rates for cogenerated power. Or if desired, only steam can be discounted by 75% and electricity charged at the utility rate (Table 13). Should the electricity be sold to the utility, the steam discount reduces to 62%. These reduced rates are the stimulus to economic development provided by the project.

In terms of 100% equity investment, real rates of return are for displaced electrical purchases and sales to the utility, respectively. With the assumed 6.5% general inflation rate, the effective rates of return are correspondingly 22% and 21%, respectively. Unfortunately, these rates fall short of the values most firms would require (about 18% in constant dollars or 26% in current year-of-service dollars). Thus, the use of lease and/or debt financing is important to the viability of the project. The project becomes viable because only 8% of the capital is equity financed, 60% of capital is IDB financed at 5% above general inflation or at 12% in current year-of-service dollars, and 32% of capital is financed at 11% above general inflation or at 18% in current year-of-service dollars.

References

Chaudhary, Z. and Porter, R., Dec. 1982: "Thermal-Economic Analysis of Cogenerated Energy Recovery by Mass-Burning Modular Refuse Incinerators", IIT Energy Management Report TR-82-2. See also: Kandula, M., Chaudhary, Z. and Porter, R.: "Cogenerated Energy Recovery from Modular Refuse Incinerators", Heat Recovery Systems, Vol. 3, No. 3, pp 203-215, 1983.

Davis, K. W., 1981: "Fuel Availability and Cost Projections for Chicago Cogeneration Application", Sargent and Lundy Engineers Memorandum to IIT I-B-2-5, Series 1.

Faddis, May 1983: Private Communication to Chicago Department of Planning.

Mastanaiah, K., Chaudhary, Z. and Porter, R., April 1982: "Feasibility Case Study Concerning Refuse-Burning Modular Incineration with Cogeneration in Chicago", IIT Energy Management Technical Memorandum TM-82-3.

Mazza, R., 1981: "Cost and Performance of Cogeneration Plants", Sargent and Lundy Engineers Memorandum to IIT I-B-4-4, Series 1.

Porter, R., Nov. 20, 1981: "Cost of Utility Interconnection", IIT Internal Memorandum I-8-4-4, Series 6.

Porter, R. W., Dec. 1982: "Technology Assessment of Cogeneration and Alternative Fuels in Chicago", Phase I Final Report Vol. 5, Urban Integrated Industrial Cogeneration Systems Analysis, Chicago Department of Planning.

Teclaw, C.E., Aug. 4, 1983: Private Communication to L. Savage of Chicago Dept. of Planning, Illinois Commerce Commission.

Van Ness, et al, Nov. 1982: "Handbook of Financial Options for Waste-to-Energy Systems for Urban Governments", Energy Task Force of the Urban Consortium for Technology Initiatives.

D Darling	SA Sweetheart, Ashland
G Griffith	W White Stokes
I Incinerator	V1 Vacant
	V2 Vacant

Revised Distribution System for Stockyards Area.

Figure 1

Table 1

Monthly Steam Consumption for Companies in Stockyards Area.

Monthly Consumption 10 ⁶ lbm Steam @ 150 psig				
Month	Darling	Griffith	White Stokes	Sweetheart Ashland
January	53	6.8	1.0	6.9
February	54	6.4	1.5	5.9
March	44	6.3	1.5	6.5
April	43	3.4	0.8	5.8
May	33	3.4	1.1	4.0
June	34	1.1	1.0	4.9
July	46	3.3	0.8	3.2
August	44	1.8	1.0	4.0
September	46	2.7	0.8	3.5
October	36	3.7	0.8	4.5
November	41	4.9	0.9	6.5
December	54	5.9	0.9	7.1

Table 2

Relative Steam Loads for Users in Stockyards Area.

Period (1)	5 Weekdays						2 Weekend Days					
	1	2	3	4	5	6	1	2	3	4	5	6
Darling	0.57	0.57	0.57	1.43	1.43	1.43	0.57	0.57	0.57	1.43	1.43	1.43
Griffith	1	1	1	1	1	1	1	1	1	1	1	1
White-Stokes	4.2	4.2	0	0	0	0	0	0	0	0	0	0
Sweetheart Ashland	1.4	1.4	1.4	1.4	1.4	1.4	0	0	0	0	0	0

(1) Four hours duration starting at 6 A.M.

Table 3

**Thermal Performance of Two Refuse-Burning Modular
Incinerators for Cogeneration.**

Boiler psig/ ^o F	Fired
Fuel	625/725
Prime Mover	Refuse Steam Turbine
Capacity (1)	
Refuse, TPD	300
MMBtu/hr (HHV)	110
Steam, lbm/hr	52,400
Electric, MW(e)	1.50
Availability (2)	
Refuse, Steam (3)	0.81
Electric (4)	0.78
Available Capacity	
Refuse, TPD	243
Steam, lbm/hr	42,444
Electric, MW(e)	1.17
Available Capacity Factor (5)	
Steam	0.975
Capacity Factor (6)	
Steam (7)	0.79
Electric (8)	0.78
Refuse (9)	0.81
Average Performance	
Steam, lbm/hr	41,396
Electricity, MW(e)	
Generated (10)	1.17
Fuel, MMBtu/hr (HHV)	
Refuse Consumed	89.10
Fuel Displaced (11)	<u>53.77</u>
Net	35.33
IHR, Btu (HHV)/kWh(e)	
	30,200

- (1) Based on Mazza (1981) except for refuse plants (Mastanaiah, Chaudhary and Porter, April 1982).
- (2) (Available capacity)/Installed capacity).
- (3) Based on planned and forced outages of 5 weeks/yr each.
- (4) Based on part-load performance at steam available capacity (Mazza, 1981) and on 96% turbogenerator availability.

- (5) (Average load)/(Available capacity).
- (6) (Average load)/(Installed capacity).
- (7) (Availability) x (Available capacity factor).
- (8) Based on cogeneration mode of operation at part load (Mazza, 1981) and on powerplant mode, up to full available capacity.
- (9) Based on part-load performance (Mazza, 1981) and on operation in incineration mode up to full available capacity.
- (10) Cogeneration mode and powerplant mode.
- (11) Based on 1091 Btu/lbm (steam) and present boiler efficiency of 84%.

Table 4
 Producer Price Index (1).

Period	PPI (2)	%/yr (3)
1976	183 (4)	-
1977	194 (4)	-
1978	209 (4)	-
1979	236 (4)	-
1980	269 (4)	-
Jan. 1981	281	-
1981	293 (4)	-
1982	299 (4)	-
1983	306	2.4 (5)
1984	321	5.0 (5)
1985	344	7.3 (5)
1986	369	7.2
1990	484	6.8 (5)
1995	660	6.0 (5)
2000	881	5.9 (5)
2005	1199	6.8 (5)
2010	1701	7.7

- (1) Formerly Wholesale Price Index.
 (2) Average for period or value at mid period.
 (3) Change relative to previous period.
 (4) U. S. DOC (1982-1983).
 (5) Based on DRI (Faddis, 1983).

Table 5

Fuel Price Projections (After Tax) for Chicago.

Energy Type	1983-\$ 10 ⁶ -Btu (HHV) 1983 1986 (1)		Real Escalation %/year 1986-2010 (1)
<hr/>			
Natural Gas			
Residential (Class 1)	5.46 (2)	5.80	2.8
<22 10 ⁶ -Btu/h (Class 2)	5.46 (2)	6.04	3.0
>22 10 ⁶ -Btu/h (Class 3)	4.77 (2)	5.27	3.0
Prime Mover Service (Class 4)	4.89 (2)	5.41	3.0
No. 2 Oil			
Retail	8.63 (3)	9.22	2.5
Wholesale/Industrial	6.91 (4)	7.45	3.0
No. 6 Oil			
	4.45 (5)	4.79	3.0
Low-S Coal			
	3.19 (6)	3.36	0.8

(1) Based on data of DRI prepared for U. S. DOE (Faddis, May 1983).

(2) Based on rates effective July 1, 1983 including 13.32% tax.

(3) Based on \$1.20/gal at 0.139 10⁶-Btu/gal.

(4) Based on 0.96/gal at 0.139 10⁶-Btu/gal.

(5) Based on \$28/bbl (42 gal) at 6.287 10⁶-Btu/bbl.

(6) Based on Davis (1981).

Table 6.

Electricity Price Projections (After Tax) for Chicago.

	<u>1983-\$/kWh(e)</u>		Real Escalation %/yr 1987-2010
	1983	1986	
Residential	0.0910	0.0965 (2)	-1.2 (2)
Industrial Rate 6L (1)			
<10 MW(e) Demand	0.0666	0.0747 (2)	-0.4 (2)
100 MW(e) Demand	0.0573	0.0643 (2)	-0.4 (2)
Utility Buyback Rider 4 (1)	0.0391	0.0359 (3)	-0.4

(1) 50% load factor during all billing factors. Rates applicable July 1, 1983.

(2) Based on Faddis (1983).

(3) Based on - 2.8%/yr escalation according to information submitted by Commonwealth Edison Co. to Illinois Commerce Commission in 1980 for 1981-1985.

Table 7

Estimates of Capital Cost in 1983 10^6 \$ for Two
Refuse-Burning Modular Incinerators for Cogeneration.

Item	Cost (1)
Incinerator Including Boiler (2)	4.36
Building	0.76
Installation	0.76
Refuse Loader	0.13
Refuse and Flyash Conveyors	0.19
Chimney and Flyash Silo	0.08
ID Fans (2)	0.02
ESP or Baghouse (2)	0.87
Water Supply and Treatment	0.54
Balance of Plant	0.38
Condenser (Backup)	0.08
Cooling Tower (Backup)	0.49
Piping (2)	1.85
Turbine	1.61
Interconnection (2,3)	0.19
Total Direct	12.31
35% Indirect	4.31
Total Cost	16.62

- (1) Based on Chaudhary and Porter (1982), adjusted for 1983 \$.
- (2) No economy of scale is assumed for multiple units. For the other items, an exponent of 0.8 is assumed except for turbines which were interpolated from Mazza (1981).
- (3) Value of \$118,700/MW(e) installed (Porter, November 20, 1981) adjusted for 1983 \$.

Table 8

Summary of General Economic Parameters (1983 \$ and 1986 Startup).

Cost of Displaced Fuel, \$/MMBtu (1)	
Natural Gas (2)	5.27
Value of Electricity, \$/kWh(e) (1)	
Displaced (3)	0.0747
Sold (4)	0.0359
Refuse Credit (Net), \$/MMBtu (5)	0.398
Real Escalation Rates, %	
Fuel	
Natural Gas (2)	3.0
Refuse Credit	0
Electricity (3)	-0.4
O&M, Etc.	0
General Inflation Rate, %	6.5
Life, Yrs	
Life Cycle	20
Depreciation	
IDB Financed	8 (SL)
Other	5 (ACRS)
Finance	
Lease	5
Lease Loan	5
Other Loan	20
Depreciation Basis, %	95
Investment Tax Credit, %	10

(1) Based on Faddis (1983).

(2) Based on Class 3 Service ($>22 \cdot 10^6$ Btuh).(3) Based on Industrial Rate 6L (<10 MW(e) demand).

(4) Based on Rider 4 (Utility Buyback).

(5) Based on net credit of \$3.50/ton and 4400 Btu(HHV)/lbm/(refuse).
Allows for O&M, etc.

Table 9

Economic Performance of Two Refuse-Burning Modular Incinerators
for Cogeneration Operated at Full Available Capacity Without
Credit for Conventional Equipment (1983 \$ and 1986 Startup).

	Use of Electricity Generated	
	Sales to Utility	Displaced Purchases
Capital Cost \$1000		
Direct Cost		
Plant (1)	12,310	12,120
Credit	0	0
Net Direct Cost	12,310	12,120
Indirect Cost (2)	4,310	4,240
Distribution Cost (3)	2,990	3,770
Total Cost	19,610	20,130
1st Yr Cash Flows, \$1000		
Incomes are Positive		
Fuel		
Consumed	-	-
Displaced (4)	2,484	2,484
Net	2,484	2,484
Refuse Credit, O&M	315	315
Electricity		
Displaced (5)	0	766
Sold	368	0
Total	368	766
Net Savings (6)	3,167	3,565
Simple Payback, Yrs	6.2	5.6

(1) Based on Chaudhary and Porter (December 1982), adjusted for 1983 \$.

(2) Based on 35% of direct cost.

(3) Based on 207 \$/ft for 12,550 ft of equally split 12-in main and 6-in condensate return with sales to utility. Without sales to utility, add 54 \$/ft for electrical cables. Add 15% indirect costs.

(4) Based on conventional equipment being fired with natural gas (Class 3).

(5) Based on Industrial Rate 6L (<10 MW(e) demand).

(6) Excludes capital charges and taxes.

Table 10

Annual Nondiscounted Cash Flows for Lessor in Current Year-of-Service Dollars (\$1000)(1).

<u>YEAR 0</u>		<u>YEAR 3</u>	
INVEST (EQUITY)	-1610	LOAN	-2069.34869
TAX CREDIT	765	LEASE	2408
NET	-845	CASH FLOW 1	0
<u>YEAR 1 (2)</u>		2	0
LOAN	-2069.34869	3	0
LEASE	2408	4	0
CASH FLOW 1	0	5	0
2	0	TAX INTEREST	395.886888
3	0	LEASE	1167.88
4	0	CASH FLOWS	0
5	0	DEPRECIA	779.05065
TAX INTEREST	568.63534	NET	345.708851
LEASE	-1167.88	<u>YEAR 4</u>	
CASH FLOWS	0	LOAN	-2069.34869
DEPRECIA	556.46475	LEASE	2408
NET	295.871404	CASH FLOW 1	0
<u>YEAR 2</u>		2	0
LOAN	-2069.34869	3	0
LEASE	2408	4	0
CASH FLOW 1	0	5	0
2	0	TAX INTEREST	285.276893
3	0	LEASE	-1167.88
4	0	CASH FLOWS	0
5	0	DEPRECIA	779.05065
TAX INTEREST	489.465563	NET	233.098856
LEASE	-1167.88	<u>YEAR 5</u>	
CASH FLOWS	0	LOAN	-2069.34869
DEPRECIA	816.1483	LEASE	2408
NET	476.385178	CASH FLOW 1	0
		2	0
		3	0
		4	0
		5	0
		TAX INTEREST	154.535878
		LEASE	-1167.88
		CASH FLOWS	0
		DEPRECIA	779.05065
		NET	104.357842

- (1) Based on 40% capital lease, Lease is 80% debt financed at 18.2% providing lessor with 25.3% return on equity, over 5 years.
- (2) 1986.

Table 11

Annual Nondiscounted Cash Flows for Lessee-Users in Current Year-of-Service Dollars (\$1000) (1).

<u>YEAR 0</u>			
INVEST (EQUITY) 0			
TAX CREDIT	1208		
NET	1208		
<u>YEAR 1 (2)</u>			
LOAN	-1596.75896		
LEASE	-2408		
CASH FLOW 1	2484		
2	315		
3	766		
4	0		
5	0		
TAX INTEREST	691.22394		
LEASE	1167.88		
CASH FLOWS	-1729.025		
DEPRECIA	783.787324		
NET	474.107301		
<u>YEAR 2</u>			
LOAN	-1596.75896		
LEASE	-2408		
CASH FLOW 1	2558.52		
2	315		
3	762.936001		
4	0		
5	0		
TAX INTEREST	681.40585		
LEASE	1167.88		
CASH FLOWS	-1763.68116		
DEPRECIA	1079.39412		
NET	796.69585		
<u>YEAR 3</u>			
LOAN	-1596.75896		
LEASE	-2408		
CASH FLOW 1	2635.2756		
2	315		
3	759.884257		
4	0		
5	0		
TAX INTEREST	670.429225		
LEASE	1167.88		
CASH FLOWS	-1799.42753		
DEPRECIA	967.446716		
NET	711.729304		
		<u>YEAR 4</u>	
		LOAN	-1596.75896
		LEASE	-2408
		CASH FLOW 1	2714.33387
		2	315
		3	756.84472
		4	0
		5	0
		TAX INTEREST	658.157358
		LEASE	1167.88
		CASH FLOWS	-1836.29662
		DEPRECIA	908.400672
		NET	679.56104
		<u>YEAR 5</u>	
		LOAN	-1596.75896
		LEASE	-2408
		CASH FLOW 1	2795.76389
		2	315
		3	753.817342
		4	0
		5	0
		TAX INTEREST	644.43741
		LEASE	1167.88
		CASH FLOWS	-1874.3219
		DEPRECIA	852.958377
		NET	650.776155
		<u>YEAR 6</u>	
		LOAN	-1596.75896
		LEASE	0
		CASH FLOW 1	2879.6368
		2	315
		3	750.802073
		4	0
		5	0
		TAX INTEREST	629.098509
		LEASE	0
		CASH FLOWS	-1913.53785
		DEPRECIA	0
		NET	1064.24057

YEAR 7
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 2966.02591
 2 315
 3 747.798864
 4 0
 5 0
 TAX INTEREST 611.949618
 LEASE 0
 CASH FLOWS -1953.98001
 DEPRECIA 0
 NET 1090.03541

YEAR 8
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 3055.00668
 2 315
 3 744.80767
 4 0
 5 0
 TAX INTEREST 592.777158
 LEASE 0
 CASH FLOWS -1995.68496
 DEPRECIA 0
 NET 1115.14759

YEAR 9
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 3146.65688
 2 315
 3 741.828439
 4 0
 5 0
 TAX INTEREST 571.342347
 LEASE 0
 CASH FLOWS -2038.69038
 DEPRECIA 0
 NET 1139.37833

YEAR 10
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 3241.05659
 2 315
 3 738.861125
 4 0
 5 0
 TAX INTEREST 547.378229
 LEASE 0
 CASH FLOWS -2083.03509
 DEPRECIA 0
 NET 1162.50189

YEAR 15
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 3757.27288
 2 315
 3 724.20165
 4 0
 5 0
 TAX INTEREST 377.848587
 LEASE 0
 CASH FLOWS -2326.29015
 DEPRECIA 0
 NET 1251.27401

YEAR 20
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 4355.70904
 2 315
 3 709.833028
 4 0
 5 0
 TAX INTEREST 81.7375042
 LEASE 0
 CASH FLOWS -2609.5629
 DEPRECIA 0
 NET 1255.95771

(1) 40% capital lease over 5 years, 60% IDB debt financed over 20 years at 11.8%. Cash flows are allowances for steam (1), refuse credit less O&M (2) and electricity (3).

(2) 1986.

Table 12

Annual Nondiscounted Cash Flows for Lessee in Current Year-of-Service Dollars (\$1000) (1).

<u>YEAR 0</u>		<u>YEAR 4</u>	
INVEST (EQUITY)	0	LOAN	-1596.75896
TAX CREDIT	1208	LEASE	-2408
NET	1208	CASH FLOW 1	1117.85972
<u>YEAR 1 (2)</u>		2	315
LOAN	-1596.75896	3	312.223148
LEASE	-2408	4	0
CASH FLOW 1	1023	5	0
2	315	TAX INTEREST	658.157358
3	316	LEASE	1167.88
4	0	CASH FLOWS	-846.365192
5	0	DEPRECIA	695.61125
TAX INTEREST	691.22394	NET	-584.392677
LEASE	1167.88	<u>YEAR 5</u>	
CASH FLOWS	-802.19	LOAN	-1596.75896
DEPRECIA	695.61125	LEASE	-2408
NET	-598.233772	CASH FLOW 1	1151.39551
<u>YEAR 2</u>		2	315
LOAN	-1596.75896	3	310.974256
LEASE	-2408	4	0
CASH FLOW 1	1053.69	5	0
2	315	TAX INTEREST	644.43741
3	314.736	LEASE	1167.88
4	0	CASH FLOWS	-862.024338
5	0	DEPRECIA	695.61125
TAX INTEREST	681.40585	NET	-581.484872
LEASE	1167.88	<u>YEAR 6</u>	
CASH FLOWS	-816.46161	LOAN	-1596.75896
DEPRECIA	695.61125	LEASE	0
NET	-592.897473	CASH FLOW 1	1185.93738
<u>YEAR 3</u>		2	315
LOAN	-1596.75896	3	309.730359
LEASE	-2408	4	0
CASH FLOW 1	1085.3007	5	0
2	315	TAX INTEREST	629.098509
3	313.477056	LEASE	0
4	0	CASH FLOWS	-878.173853
5	0	DEPRECIA	695.61125
TAX INTEREST	670.429225	NET	660.444682
LEASE	1167.88		
CASH FLOWS	-831.182212		
DEPRECIA	695.61125		
NET	-588.242943		

YEAR 7
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 1221.5155
 2 315
 3 308.491438
 4 0
 5 0
 TAX INTEREST 611.949618
 LEASE 0
 CASH FLOWS -894.828364
 DEPRECIA 695.61125
 NET 660.980479

YEAR 8
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 1258.16096
 2 315
 3 307.257472
 4 0
 5 0
 TAX INTEREST 592.777158
 LEASE 0
 CASH FLOWS -912.002942
 DEPRECIA 695.61125
 NET 660.044941

YEAR 9
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 1295.90579
 2 315
 3 306.028442
 4 0
 5 0
 TAX INTEREST 571.342347
 LEASE 0
 CASH FLOWS -929.713105
 DEPRECIA 0
 NET -38.1954836

YEAR 10
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 1334.78297
 2 315
 3 304.804329
 4 0
 5 0
 TAX INTEREST 547.378229
 LEASE 0
 CASH FLOWS -947.974839
 DEPRECIA 0
 NET -42.7682759

YEAR 15
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 1547.37929
 2 315
 3 298.756816
 4 0
 5 0
 TAX INTEREST 377.848587
 LEASE 0
 CASH FLOWS -1048.15101
 DEPRECIA 0
 NET -105.92528

YEAR 20
 LOAN -1596.75896
 LEASE 0
 CASH FLOW 1 1793.83669
 2 315
 3 292.829291
 4 0
 5 0
 TAX INTEREST 81.7375042
 LEASE 0
 CASH FLOWS -1164.808
 DEPRECIA 0
 NET -278.163475

(1) 40% capital lease over 5 years. 60% IDB debt financed at 11.8% over 20 years. Includes steam (Cash Flow 1) and electricity (Cash Flow 3) discounts of 58.8%. Assumes minimum acceptable return on investment of 25.7%.

(2) 1986.

Table 13

Effect of Financing for the Two Refuse-Burning Modular Incinerators for Cogeneration With and Without Sales to Utility, 1983 \$ and 1986 Startup (1).

	Use of Electricity Generated			
	Sales to Utility		Displaced Purchases	
	100% Equity	60% Debt (2) 40% Lease (3)	100% Equity	60% Debt (2) 40% Lease (3)
Loan Rate	-	5.0	-	5.0
Lease Loan Rate	-	10.0	-	10.0
Equity	100	-	100	-
ROI, %	13.9	-	14.9	-
Discount Rate, %	-	18.0	-	18.0
Allowable Discounts, %				
Based on Steam Only	-	62.3	-	74.7
Based on Steam and Electricity	-	-	-	58.8

- (1) Loan, ROI and discount rates are relative to general inflation of 6.5%.
- (2) IDB financing for taxable owner.
- (3) Lessor ROI = 18% on 20% equity with debt financed at 11%. Lease and loan payments are levelized in current (year-of-service) dollars over 5 years.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

**CASE STUDY OF REFUSE-FIRED COGENERATION
FOR CALUMET INDUSTRIAL AREA**

Energy Management Memorandum TM-83-3

**Robert W. Porter, P.E.
Professor**

**Hayder Abdul-Razzak
Research Assistant**

**Department of Mechanical Engineering
Illinois Institute of Technology
Chicago, Illinois 60616**

October, 1983

**Topical Report prepared under Subcontract 50391
Chicago Department of Planning
U.S. Department of Energy Grant DE-FG02-80CS40337**

Project Description

The project "Urban Integrated Industrial Cogeneration Systems Analysis" concerns the identification and resolution of institutional, legal and economic issues of cogeneration in the urban environment. It also deals with technical matters particularly including thermal-economic analysis of cogeneration within the context of regulation, financing, optimization and design. The work is applied using a case study approach to cogeneration opportunities identified by a survey of companies and institutions in the City of Chicago performed in cooperation with Commonwealth Edison Company and Peoples Gas Company and as identified by other sources of the Chicago Department of Planning and Illinois Institute of Technology. The project attempts to bring to the attention of the industrial-commercial sector the opportunities and benefits of cogeneration in stimulating economic development through efficient energy utilization.

Table of Contents

	Page
Project Description	210
Summary	211
Introduction	213
Site Considerations	214
Thermal-Economic Analysis	215
Single User	215
Multiple Users	216
References	217

Summary

The Calumet area was analyzed as a case study for cogenerated energy recovery from refuse using modular water-wall mass-burning incinerators. The facility is considered to serve either a single local company (Republic Steel) or three companies (Republic Steel, Cargill and General Mills). The situation is complicated in that Republic Steel needs an average of 113,000 lbm/hr of 300 psig/680°F steam which requires a modified reheat incinerator for the purposes of cogeneration. The other users employ an average of 49,000 lbm/hr of 150 psig saturated-vapor steam which does not need reheat. However, excess steam from the higher pressure supply can be used for distribution to users at 150 psig by throttling down in pressure. This reduces the need for additional incinerators.

Revenues for the plant would include a tipping fee for refuse processing and income from steam sales. Electricity is best utilized to displace purchases of the users from the local utility, but can also be sold to the utility according to federal regulations governing cogeneration and small power production from alternative energy.

For the case of the single steam user, the optimum system has a rated capacity of 750 TPD of refuse, 120,000 lbm/hr of 300 psig/680°F steam and 1.6 MW(e) of electricity. It would supply about 76% of the Republic Steel's steam generated from purchased fuels. Steam and electricity could be discounted about 75% relative to conventional cost for the case of 60% industrial development bond and 40% leveraged lease financing.

For the multiple-user system, the combined rated capacities are 900 TPD of refuse, 120,000 lbm/hr of 300 psig/680°F steam, 26,200 lbm/hr of 150 psig saturated-vapor steam, and 2.33 MW(e) of electricity. About 69% of the combined steam requirements of the three users would be met. Steam and electricity could be discounted about 74% relative to conventional cost, by employing a typical 60% industrial development bond and 40% leveraged lease financing plan.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Introduction

During Phase I of the present project, it was determined that the Calumet area was potentially attractive for a refuse-fired cogeneration system (Porter, Dec. 1982). This area was also identified by Environdyne Engineers, Inc. (June 1982) in a study performed for Chicago Department of Public Works as one where the system would be desirable in the future as two nearby landfill sites are depleted in 5-6 years. Based on this potential and the desire of the City to promote industrial development in the area, the present study was undertaken.

The present study resulted in the identification and surveying of energy needs of three local companies which appear capable of benefiting from the proposed system:

Republic Steel
Cargill
General Mills

Republic Steel is the largest steam user, consuming monthly averages of 72,000 - 147,000 lbm/hr of 300 psig/680°F steam. The combined use ranges from 110,000 - 210,000 lbm/hr, the other users employing 150 psig saturated steam. Republic Steel alone can easily consume all of the several megawatts of electricity cogenerated in a steam-turbine-based cogeneration plant producing steam in the required amounts.

It is proposed to utilize multiple 150 TPD water-wall incinerators which would consume refuse continuously to the extent of available capacity, about 81% of installed capacity (Chaudhary and Porter, Dec. 1982). The optimum capacity would be determined by economy of scale which is favored more by an increasingly large facility, and by percentage use of steam production which is favored less by an increasingly large facility beyond those for which full output can be used.

Electrical output of several megawatts can be sold to the local utility under provisions of PURPA (Public Utility Regulatory Policies Act of 1978). Or, potentially more advantageously, it can be used to displace purchases of a local user of electricity (Teclaw, Aug. 4, 1983). However, such displacement is currently not an established practice and so both options are analyzed here.

The proposed modular system employs 150-TPD refuse-incineration boilers generating 625 psig/725°F steam suitable for expansion in topping (back-pressure) steam turbines prior to utilization. The particular system analyzed is available from Basic Environmental Engineering Company, Inc. of Glen Ellyn, Illinois. It utilizes an efficient water-wall construction with an articulating grate suitable for mass burning of municipal refuse with minimal preprocessing. Gas cleanup to be supplied with the unit is anticipated to meet environmental requirements. The system based on 150-psig saturated steam utilization produces 26,200 lbm/hr of steam and 0.75 MW(e) of electricity under rated conditions (Chaudhary and Porter, Dec. 1982). However, when the steam is expanded to only 300 psig as required by Republic Steel, only 0.32 MW(e) of electricity is produced.

Further, the steam must be reheated in the boiler in order to satisfy the temperature requirement of 680°F. And, the steam production is reduced to 24,000 lbm/hr. A heat balance is summarized in Figure 1 for the modified reheat incinerator.

The present analysis is centered upon the determination of the optimum number of modified reheat incinerators in order to serve part or all of the Republic Steel requirement at 300 psig. Excess capacity of these units together with an optimum number of non-reheat units are separately considered to serve Cargill and General Mills at 150 psig, additionally, as an industrial district steam supply. The excess capacity of the reheat units would be throttled (dropped in pressure) before being distributed. The system could be expanded in the future with additional units being added of the required type depending on present or new-user needs.

The present analysis is based on an economic life cycle commencing in 1986 and lasting for 20 years. Experience with incinerators using municipal refuse suggests that longer life cycles are unrealistic. Financing for the purpose of optimization is considered on the basis of 100% equity. However, the selected systems are also analyzed assuming a 60% Industrial Development Bond (IDB) and a 40% leveraged lease, as might typically be employed for the present application. The owner is considered taxable and could be one or more of the steam users, perhaps separately incorporated, or could be a "third party". The case of utility ownership is not considered here but is another possibility. For 100% equity investment, results are summarized in terms of rate of Return on Investment (ROI). For IDB-lease financing, results are cast in terms of maximum allowable percentage discount to users calculated with savings credited to either steam or both steam and electricity utilized.

Site Considerations

The site of the proposed incinerator and cogeneration plant is shown in Figure 2. The facility is located across the canal from Republic Steel which is near 111th Street and South Burley Avenue. The piping and electrical cables (where appropriate) are considered to span the canal along an existing utility bridge. The distance from the facility to the point of connection at the existing Republic Steel power plant is about 3300 ft.

Also shown in Figure 2 are additional distribution lines to General Mills and Cargill which are on the same side of the canal as the proposed facility. The additional distribution distance is about 13,390 ft. About 40 acres of land appear to be suitable for the site of the facility. Ownership and the present limited use have not been determined for the tract.

Monthly consumptions of steam generated from purchased fuels, for the proposed three users are given in Table 1. The relative operation of each user by shifts is given in Table 2. The site is presumed to have enough space for refuse storage to permit continuous operation during periods of non-collection, evenings and weekends.

Thermal-Economic Analysis

Single User

First, we consider only Republic Steel which requires the modified reheat incinerator (Figure 1). Performance factors are summarized in Table 3 for 3 to 6 modular units. Notable are (1) the rated capacities which determine the capital costs of the facility and (2) the average performances which determine the annual cash flows. The annual cash flows are due to incomes from steam sales, or equivalently fuel savings, income from electricity sales, or savings of displaced purchases, and net income due to tipping fees, refuse transportation savings, etc. less operation and maintenance costs.

All costs in the present study were adjusted to account for general inflation as reflected by the Producer Price Index (PPI) of Table 4. In particular, projections for the project life cycle (1986-2005) indicate an inflation rate averaging about 6.5%.

Projections for fuel costs are given in Table 5. In the present case, it is assumed that steam revenue or savings is coupled to the cost of Class 3 natural gas service with a predicted 3% compound annual real escalation (relative to general inflation). The value of steam is computed by assuming a boiler efficiency of 84% in the existing power plant.

The projected values of cogenerated electricity are given in Table 6. We consider cases of (1) sales to the local electric utility under Rider 4 and (2) displaced purchases under Rate 6L. While the latter option is apparently more advantageous, the charge for backup power has been neglected here.

A review of the net credit for processing refuse including charges for operation and maintenance (O&M) has indicated that previous estimates (Chaudhary and Porter, Dec. 1982) are correct when adjusted for inflation in the interim (Table 7). The net credit is \$3.50/ton (refuse) in 1983 dollars. The credit includes a tipping fee set at alternative disposal costs plus collection savings, less O&M and ash disposal costs. No net savings has been accrued to the City of Chicago for using the facility. Indirect benefits would be those of economic development and conservation of landfill.

The capital cost of the plant for 1 to 6 modular incinerators including interconnection with the utility but excluding distribution piping and cable are detailed in Table 8. The costs will be adjusted depending on the disposition of generated electricity.

General economic parameters are listed in Table 9.

Capital costs, and the values of steam, electricity and refuse processed during the first year of operation (1986) are given in Table 10. Based on a real interest rate (minimum acceptable return on investment) of 18%, relative to general inflation, the case of sales of electricity to the local utility has an optimum number of 5 modular incinerators (rated capacities of 750 TPD of refuse, 120,000 lbm/hr of 300 psig/680°F steam and

1.6 MW(e) of electricity). The net present worth is \$2,065,000 in 1983 dollars. At 18% interest, this amount levelizes to \$386,000 per year which can be regarded as the equivalent uniform annual savings of the project based on equity investment and in 1983 dollars. The case of five modular units would supply about 76% of the purchased-fuel steam requirements of Republic Steel.

The case of 5 units with displaced purchases of electricity yields a present worth of \$3,792,000 in 1983 dollars. This levelizes to an equivalent uniform annual savings of \$709,000.

Results for alternative financing are given in Table 11. For 100% equity financing, the ROI are 19.6 and 21.0 %, respectively, for the cases of sales of electricity to the utility and displaced purchases.

The case of the 60% debt (IDB) and 40% lease is based on levelized loan and lease payments in year of service dollars. Financial options are discussed in detail by Van Ness, et al (Nov. 1982). For sales of electricity to the utility, steam can be discounted by 78% relative to conventional generation. For the case of displaced purchases of electricity, the discount increases to 87%. Or both steam and electricity can be discounted by 75%. These savings appear to be very attractive.

Multiple Users

As an option, we consider an extended system designed to serve part or all of the steam requirements of Cargill and General Mills. In addition to the extended distribution system previously discussed, various numbers of incinerator boilers are analyzed in order to provide steam to users at 150 psig (Table 12). Excess capacity of the modified reheat incinerators to be used for Republic Steel is assumed also available. General economic parameters are taken to be the same as described for the single-user system of the previous section. Results of the present-worth method for system optimization are given in Table 13. The optimum number of additional modular units is one. The combined capacities of the reheat and non-reheat incinerators are: 900 TPD of refuse, 120,000 lbm/hr of 300 psig/680°F steam, 26,200 lbm/hr of 150 psig saturated steam, and 2.33 MW(e) of electricity. Approximately 55% of the steam needs of Cargill and General Mills would be met in addition to 76% of the needs of Republic Steel. The combined need met would be 69%. The present worth of the economic choice with sales of electricity to the utility is \$2,390,000 in 1983 dollars. At 18% interest, this amount is equivalent to a uniform annual savings of \$447,000 in 1983 dollars. For displaced purchases of electricity, these amounts increase to a present worth of \$3,845,000 or an equivalent uniform annual savings of \$718,000.

Results are summarized in Table 14 for the cases of equity and debt-lease financing. For, 100% equity financing, the ROI are 19.5 and 20.3%, respectively, for the cases of sales of electricity to the utility and displaced purchases.

The case of 60% debt (IDB) and 40% lease is based on levelized loan and lease payments in year of service dollars. For sales of electricity

to the utility, steam can be discounted by 77% relative to conventional generation. For the case of displaced purchases of electricity, the discount increases to 84%. Or both steam and electricity can be discounted by 74%. These savings also appear to be very attractive.

References

Basic, J., 1983: Private Communication to R. Porter of IIT, Basic Environmental Engineering Co., Inc.

Chaudhary, Z. and Porter, R., Dec. 1982: "Thermal-Economic Analysis of Cogenerated Energy Recovery by Mass-Burning Modular Refuse Incinerators", IIT Energy Management Report TR-82-2. See also: Kandula, M., Chaudhary, Z. and Porter, R: "Cogenerated Energy Recovery from Modular Refuse Incinerators", Heat Recovery Systems, Vol. 3, No. 3, pp. 203-215, 1983.

Davis, K. W., 1981: "Fuel Availability and Cost Projections for Chicago Cogeneration Application", Sargent and Lundy Engineers Memorandum to IIT, I-B-2-5, Series 1.

Envirodyne Engineers, Inc., June 1982: "Chicago Resource Recovery Study Phase II - Volume II - June 1982, Prepared for Chicago Department of Public Works.

Faddis, J., May 1983: "Private Communication to Chicago Department of Planning.

Mastanaiah, K., Chaudhary, Z. and Porter, R., April 1982: "Feasibility Case Study Concerning Refuse-Burning Modular Incineration with Cogeneration in Chicago", IIT Energy Management Technical Memorandum TM-82-3.

Mazza, R., 1981: "Cost and Performance of Cogeneration Plants", Sargent and Lundy Engineers Memorandum to IIT I-B-4-4, Series 1.

Porter, R., Nov. 20, 1981: "Cost of Utility Interconnection", IIT Internal Memorandum I-B-4-4, Series 6.

Porter, R. W., Dec. 1982: "Technology Assessment of Cogeneration and Alternative Fuels in Chicago", Phase I Final Report Vol. 5, Urban Integrated Industrial Cogeneration Systems Analyses, Chicago Department of Planning.

Teclaw, C. E., Aug. 4, 1983: Private Communication to L. Savage of Chicago Department of Planning, Illinois Commerce Commission.

Van Ness, et al, Nov. 1982: "Handbook of Financial Options for Waste-to-Energy Systems for Urban Governments", Energy Task Force of the Urban Consortium for Technology Initiatives.

218

Figure 2

Calumet Area Site for Refuse-Fired Cogeneration Plant.

Table 1

Monthly Steam Consumption for Companies in
Calumet Area

	10 ⁶ -lbm Steam		
	Republic Steel (300 psig)	Cargill (150 psig)	General Mills (150 psig)
January	102.7	22.4	17.7
February	102.4	24.8	17.7
March	73.7	23.2	20.7
April	86.9	21.3	11.1
May	61.7	16.8	10.7
June	52.4	18.3	14.5
July	70.4	18.9	11.5
August	77.3	16.6	11.8
September	70.4	16.6	13.4
October	82.7	23.4	12.2
November	98.9	22.3	15.2
December	107.7	27.9	21.0

Table 2

Relative Steam Loads for Users in Calumet Area

Period (1)	5 Weekdays			Saturdays			Sundays		
	1	2	3	1	2	3	1	2	3
Republic Steel	1	1	1	1	1	1	1	1	1
Cargill	1	1	1	0	0	0	0	0	0
General Mills	1	1	1	1	1	1	0	0	0

(1) Eight hours duration.

Table 3

**Thermal Parameters for Modified Reheat Incinerators
with Cogeneration for Republic Steel Steam Supply**

	Number of Incinerators			
	3	4	5	6
Installed Capacities (1)				
Refuse, TPD	450	600	750	900
Steam Supply, lbm/hr	72,000	96,000	120,000	144,000
Net Electricity, MW(e)	0.95	1.26	1.58	1.89
Availability (2)				
Refuse, Steam (3)	0.81	0.81	0.81	0.81
Electric (4)	0.78	0.78	0.78	0.78
Available Capacity				
Refuse, TPD	365	486	608	729
Steam, lbm/hr	58,320	77,760	97,200	116,640
Electric, MW(e)	0.77	0.98	1.23	1.47
Available Capacity Factor (5)				
Steam	1.00	0.97	0.88	0.78
Capacity Factor (6)				
Steam (7)	0.81	0.79	0.71	0.63
Electric (8)	0.78	0.78	0.78	0.78
Refuse (9)	0.81	0.81	0.81	0.81
Average Performance				
Refuse, TPD	364	486	608	729
Steam, lbm/hr	58,300	75,350	85,600	91,050
Electricity, MW(e) (10)	0.77	0.98	1.23	1.47
Fuel, MMBtuh				
Refuse (11)	133	178	223	267
Displaced (12)	87	112	128	136
Net	46	66	95	131

(1) Based on Mazza (1981) except for refuse plants (Mastanaiah, Chaudhary and Porter, April 1982).

(2) (Available capacity)/Installed capacity).

(3) Based on planned and forced outages of 5 weeks/yr each.

(4) Based on part-load performance at steam available capacity (Mazza, 1981) and on 96% turbogenerator availability.

(5) (Average load)/(Available capacity).

(6) (Average load)/(Installed capacity).

(7) (Availability) x (Available capacity factor).

- (8) Based on cogeneration mode of operation for steam load (Mazza, 1981) with balance on powerplant mode, up to full available capacity.
- (9) Based on part-load performance (Mazza, 1981) and on operation in incineration mode up to full available capacity.
- (10) Cogeneration mode and powerplant mode.
- (11) Based on 4400 B/lbm(refuse),
- (12) Based on 1252 Btu/lbm(steam) and present boiler efficiency of 84%.

Table 4

Producer Price Index (1)

Period	PPI (2)	%/yr (3)
1976	183 (4)	-
1977	194 (4)	-
1978	209 (4)	-
1979	236 (4)	-
1980	269 (4)	-
Jan. 1981	281	-
1981	293 (4)	-
1982	299 (4)	-
1983	306	2.4 (5)
1984	321	5.0 (5)
1985	344	7.3 (5)
1986	369	7.2
1990	484	6.8 (5)
1995	660	6.0 (5)
2000	881	5.9 (5)
2005	1199	6.8 (5)
2010	1701	7.7

- (1) Formerly Wholesale Price Index.
 (2) Average for period or value at mid period.
 (3) Change relative to previous period.
 (4) U. S. DOC (1982-1983).
 (5) Based on DRI (Faddis, 1983).

Table 5

Fuel Price Projections (After Tax) for Chicago

Energy Type	1983-\$/10 ⁶ -Btu (HHV)		Real Escalation %/year 1986-2010 (1)
	1983	1986 (1)	
Natural Gas			
Residential (Class 1)	5.46 (2)	5.80	2.8
<22 10 ⁶ -Btuh (Class 2)	5.46 (2)	6.04	3.0
>22 10 ⁶ -Btuh (Class 3)	4.77 (2)	5.27	3.0
Prime Mover Service (Class 4)	4.89 (2)	5.41	3.0
No. 2 Oil			
Retail	8.63 (3)	9.22	2.5
Wholesale/Industrial	6.91 (4)	7.45	3.0
No. 6 Oil	4.45 (5)	4.79	3.0
Low-S Coal	3.19 (6)	3.36	0.8

(1) Based on data of DRI prepared for U. S. DOE (Faddis, May 1983).

(2) Based on rates effective July 1, 1983 including 13.32% tax.

(3) Based on \$1.20/gal at 0.139 10⁶-Btu/gal.

(4) Based on 0.96/gal at 0.139 10⁶-Btu/gal.

(5) Based on \$28/bbl (42 gal) at 6.287 10⁶-Btu/bbl.

(6) Based on Davis (1981).

Table 6

Electricity Price Projections (After Tax) for Chicago

	<u>1983-\$/kWh(e)</u>		Real Escalation %/yr 1987-2010
	1983	1986	
Residential	0.0910	0.0965 (2)	-1.2 (2)
Industrial Rate 6L (1)			
<10 MW(e) Demand	0.0666	0.0747 (2)	-0.4 (2)
100 MW(e) Demand	0.0573	0.0643 (2)	-0.4 (2)
Utility Buyback Rider 4 (1)	0.0391	0.0359 (3)	-0.4

(1) 50% load factor during all billing factors. Rates applicable July 1, 1983.

(2) Based on Faddis (1983).

(3) Based on - 2.8%/yr escalation according to information submitted by Commonwealth Edison Co. to Illinois Commerce Commission in 1980 for 1981-1985.

Table 7

Calculation of Credit for Refuse Processing

	1983-\$/ton
Tipping Fee (Income)	
Alternate Disposal	
Transportation	\$6.81
Drop Fee	11.87
Collection Savings	<u>3.56</u>
	\$22.24
O&M, Etc. (Expense)	
Plant	\$18.36
Ash Disposal	<u>0.38</u>
	\$18.74
Net Credit (Income less Expense)	\$3.50

Table 8

Estimates of Capital Cost in 1983 \$ for Refuse-Burning
Modular Incinerators with Cogeneration (1)

	Number of Incinerators (4)					
	1	2	3	4	5	6
Incinerator Including Boiler (2)	2.18(2.28)	4.36(4.56)	6.53(6.83)	8.71(9.11)	10.89(11.39)	13.07(13.67)
Building	0.44	0.76	1.05	1.32	1.42	1.83
Installation	0.44	0.76	1.05	1.32	1.42	1.83
Refuse Loader	0.08	0.13	0.19	0.23	0.27	0.32
Refuse and Flyash Conveyors	0.11	0.19	0.26	0.33	0.39	0.46
Chimney and Flyash Silo	0.04	0.08	0.11	0.13	0.15	0.19
ID Fans (2)	0.01	0.02	0.03	0.04	0.05	0.07
ESP or Baghouse (2)	0.44	0.87	0.13	0.17	0.22	0.26
Water Supply and Treatment	0.54	0.54	0.64	0.74	0.88	1.02
Balance of Plant	0.22	0.38	0.52	0.66	0.78	0.91
Condenser (Backup)	0.04	0.08	0.11	0.13	0.15	0.19
Cooling Tower (Backup)	0.28	0.49	0.69	0.86	1.02	1.29
Piping (2)	1.85	1.85	1.85	1.85	1.85	1.85
Turbine	1.61	1.61	1.66	1.67	1.69	1.71
Interconnection (2,3)	0.09	0.19	0.27	0.36	0.45	0.53
Total Direct	8.36(8.46)	12.31(12.51)	15.07(15.37)	18.52(18.92)	21.64(22.14)	25.42(26.02)
35% Indirect	2.93(2.96)	4.31(4.38)	5.27(5.38)	6.48(6.62)	7.57(7.75)	8.90(9.11)
Total Cost	11.29(11.42)	16.62(16.89)	20.34(20.75)	25.00(25.54)	29.21(29.89)	34.32(35.13)

- (1) Based on Chaudhary and Porter (1982), adjusted for 1983 \$.
- (2) No economy of scale is assumed for multiple units. For the other items, an exponent of 0.8 is assumed except for turbines which were interpolated from Mazza (1981).
- (3) Value of \$118,700/MW(e) installed (Porter, November 20, 1981) adjusted for 1983 \$.
- (4) Values in parentheses are for modified reheat incinerators with steam supply delivered at 300 psig rather than 150 psig (Basic, 1983).

Table 9

Summary of General Economic Parameters (1983 \$ and 1986 Startup).

Cost of Displaced Fuel, \$/MMBtu (1)	
Natural Gas (2)	5.27
Value of Electricity, \$/kWh(e) (1)	
Displaced (3)	0.0747
Sold (4)	0.0359
Refuse Credit (Net), \$/MMBtu (5)	0.398
Real Escalation Rates, %	
Fuel	
Natural Gas (2)	3.0
Refuse Credit	0
Electricity (3)	-0.4
O&M, Etc.	0
General Inflation Rate, %	6.5
Life, Yrs	
Life Cycle	20
Depreciation	
IDB Financed	8 (SL)
Other	5 (ACRS)
Finance	
Lease	5
Lease Loan	5
Other Loan	20
	95
Depreciation Basis, %	
Investment Tax Credit, %	10

(1) Based on Faddis (1983).

(2) Based on Class 3 Service ($>22 \times 10^6$ Btuh).(3) Based on Industrial Rate 6L (<10 MW(e) demand).

(4) Based on Rider 4 (Utility Buyback).

(5) Based on net credit of \$3.50/ton and 4400 Btu(HHV)/lbm/(refuse).
Allows for O&M, etc.

Table 10

Economic Performance of Refuse-Burning Modular Incinerators with Cogeneration for Republic Steel Without Credit for Conventional Equipment (1983 \$ and 1986 Startup).

	Sales to Utility				Use of Electricity			
	Number of Units				Displaced Purchases			
	3	4	5	6	3	4	5	6
Capital Cost \$1000								
Direct Cost								
Plant	15,370	18,920	22,140	26,020	15,100	18,560	21,690	25,490
Credit	0	0	0	0	0	0	0	0
Net Direct Cost	15,370	18,920	22,140	26,020	15,100	18,560	21,690	25,490
Indirect Cost (35%)	5,380	6,620	7,750	9,110	5,290	6,500	7,590	8,920
Distribution Cost(1)	790	790	790	790	990	990	990	990
Total Cost	21,540	26,330	30,680	35,920	21,380	26,050	30,270	35,400
1st Yr Cash Flows, \$1000								
Incomes are Positive								
Fuel Displaced (2)	4,014	5,188	5,894	6,269	4,014	5,188	5,894	6,269
Refuse Credit, O&M	467	621	777	932	467	621	777	932
Electricity								
Displaced (3)	0	0	0	0	622	825	1,035	1,238
Sold (4)	299	397	497	595	0	0	0	0
Total	299	397	497	595	622	825	1,035	1,238
Net Savings	4,780	6,206	7,168	7,796	5,103	6,634	7,706	8,439
Simple Payback, Yrs	4.51	4.24	4.28	4.61	4.19	3.93	3.93	4.19
Present Worth	700.55	1982.17	2065.32	489.25	1680.12	3325.22	3791.99	2572.77
Economic Choice			*				*	

- (1) Based on 207 \$/ft for 3300 ft of 12-inch main and 6-inch condensate return. Add 54 \$/ft for electric cables in case of displaced purchases of electricity.
- (2) Class 3 service of natural gas.
- (3) Rate 6L.
- (4) Rider 4.

Table 11

Effect of Financing for the Five Modified Refuse-Burning Modular Incinerators with Cogeneration for Republic Steel Only, With and Without Sales to Utility, 1983 \$ and 1986 Startup.

	Use of Electricity Generated			
	Sales to Utility		Displaced Purchases	
	100% Equity	60% Debt 40% Lease	100% Equity	60% Debt 40% Lease
Loan Rate, %	-	5.0	-	5.0
Lease Loan Rate, %	-	11.0	-	11.0
Lessor ROE (20% Equity), %	-	18.0	-	18.0
ROI, %	19.61	-	20.98	-
Discount Rate, %	-	18.0	-	18.0
Allowable Discounts, %				
Based on Steam Only	-	78.27	-	86.83
Based on Steam and Electricity	-	-	-	75.23

Table 12

Thermal Parameters for Refuse-Burning Modular Incinerators with Cogeneration
for Calumet Area Including Republic Steel, Cargill, and General Mills

	Alternative		
Number of Incinerators			
Reheat	5	5	5
Conventional	1	2	3
Total	6	7	8
Installed Capacities			
Refuse, TPD	900	1050	1200
Steam Supply, lbm/hr			
300 psig	120,000	120,000	120,000
150 psig	26,200	52,400	78,600
Total	146,200	172,400	198,600
Net Electricity, MW(e)	2.33	3.08	3.83
Availability			
Refuse, Steam	0.81	0.81	0.81
Electric	0.78	0.78	0.78
Available Capacity			
Refuse, TPD	729	851	972
Steam, lbm/hr			
300 psig	97,200	97,200	97,200
150 psig	21,200	42,400	63,700
Total	118,400	139,600	160,900
Electricity, MW(e)	1.82	2.40	2.99
Available Capacity Factor			
Steam	0.93	0.86	0.78
Capacity Factor			
Steam	0.75	0.70	0.63
Electric	0.78	0.78	0.78
Refuse	0.81	0.81	0.81
Average Performance			
Steam, lbm/hr			
for Republic Steel	85,600	85,600	85,600
for Cargill and General Mills	26,900	34,600	39,480
Total	112,500	120,200	125,080
Electricity, MW(e)			
Generated	1.82	2.40	2.99
Fuel, MM Btu/hr (HHV)			
Refuse Consumed	267.30	311.85	356.40
Fuel Displaced	162.52	172.52	178.86
	104.78	139.33	177.54

Table 13

Economic Performance of Refuse-Burning Modular Incinerators with Cogeneration for Calumet Area Operated Without Credit for Conventional Equipment (1983 \$ and 1986 Startup).

	Use of Electricity							
	Sales to Utility				Displaced Purchases			
	Number of Units ★				Number of Units ★			
	5	6	7	8	5	6	7	8
Capital Cost \$1000								
Direct Cost								
Plant	22,140	25,920	29,290	32,660	21,690	25,390	28,670	31,950
Credit	0	0	0	0	0	0	0	0
Net Direct Cost	22,140	25,920	29,290	32,660	21,690	25,390	28,670	31,950
Indirect Cost	7,750	9,070	10,250	11,430	7,590	8,890	10,040	11,180
Distribution Cost	790	3,970	3,970	3,970	990	5,010	5,010	5,010
Total Cost	30,680	38,960	43,510	48,060	30,270	39,290	43,720	48,140
1st Yr Cash Flows, \$1000								
Incomes are Positive								
Fuel Displaced	5,894	7,508	7,970	8,263	5,894	7,508	7,970	8,263
Refuse Credit, O&M	777	932	1,087	1,243	777	932	1,087	1,243
Electricity								
Displaced	0	0	0	0	1,035	1,192	1,572	1,958
Sold	497	573	755	941	0	0	0	0
Total	497	573	755	941	1,035	1,192	1,572	1,958
Net Savings	7,168	9,013	9,812	10,447	7,706	9,632	10,629	11,464
Simple Payback, Yrs	4.28	4.32	4.43	4.60	3.93	4.08	4.11	4.20
Present Worth	2,065	2,390	1,776	635	3,325	3,845	3,847	3,333
Economic Choice		*				*		

* Five units are modified reheat type for Republic Steel.

Table 14

Effect of Financing for Refuse-Burning Modular Incinerators with Cogeneration for Calumet Area, 1983 \$ and 1986 Startup.

	Use of Electricity Generated			
	Sales to Utility		Displaced Purchases	
	100% Equity	60% Debt 40% Lease	100% Equity	60% Debt 40% Lease
Loan Rate,%	-	5.0	-	5.0
Lease Loan Rate,%	-	11.0	-	11.0
Lessor ROE(20% Equity),%	-	18.0	-	18.0
ROI,%	19.5	-	20.3	-
Discount Rate,%	-	18.0	-	18.0
Allowable Discounts,%				
Based on Steam Only	-	77.0	-	83.9
Based on Steam and Electricity	-	-	-	73.6

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Appendix 5.3

Fauske & Associates, Inc.

16W070 West 83rd Street

Burr Ridge, Illinois 60521

(312) 323-8750

UIICSA Topical Report

INDUSTRIAL COGENERATION FEASIBILITY STUDY:

FORD CITY COMMERCIAL/INDUSTRIAL DISTRICT

By:

Thomas J. Marciniak

David P. Kuhaneck

Prepared For:

Urban Integrated Industrial Cogeneration
Systems Analysis Project
Chicago Department of Planning
City Hall, Room 1000
121 North LaSalle Street
Chicago, Illinois 60602

October, 1983

Urban Integrated Industrial Cogeneration System Analysis

PROJECT DESCRIPTION

The project, "Urban Integrated Industrial Cogeneration Systems Analysis," addresses the identification and resolution of institutional, legal and economic issues of cogeneration in the urban environment. It also focuses on technical matters particularly, including the thermal-economic analysis of cogeneration within the context of regulation, financing, design, and optimization. The work is applied using a case study approach to cogeneration opportunities identified by a survey of industries and institutions in the City of Chicago in cooperation with Peoples Gas Company and Commonwealth Edison Company. The project attempts to bring to the attention of the industrial-commercial sector the opportunities and benefits of cogeneration in conserving energy and stimulating economic development.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	243
1.0 INTRODUCTION	244
1.1 Background	244
1.2 Report Organization	246
2.0 SITE DESCRIPTION	248
2.1 General	248
2.2 Ford City Shopping Center and Industrial Park	250
2.2.1 General Considerations	250
2.2.2 Main Structures and Tenants	252
2.2.3 Other Tenants	254
2.3 Vacant Land	255
3.0 SITE ENERGY REQUIREMENTS	257
3.1 General	257
3.2 Electricity Requirements	257
3.3 Thermal Energy Requirements	261
4.0 SYSTEM DESIGN	266
4.1 General	266
4.2 System Technological Options	268
4.2.1 Steam Turbine Systems	269
4.2.2 Diesel Engine Systems	269
4.2.3 Gas Turbine Systems	270
4.3 Ford City Cogeneration System	271
5.0 ECONOMIC EVALUATION	276

TABLE OF CONTENTS (Continued)

	<u>Page</u>
5.1 General	276
5.1.1 Electricity Costs	276
5.1.2 Fuel Costs	279
5.1.3 Future Cost Expectations	278
5.2 Economic Assumptions	280
5.3 Results	282
6.0 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS	287
6.1 Results Summary	287
6.2 Conclusions	289
6.3 Recommendations	290
<u>APPENDIX A</u> -- Cogeneration System Economic Analysis	293

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
2.1	General location of the Ford City Shopping and Industrial Center	249
2.2	Ford City Shopping Center and Industrial Park	251
3.1	Annual variation of Ford City total and non-HVAC electricity demand	259
3.2	Annual variation of total electrical usage	260
3.3	Annual load factor variation at Ford City	262
3.4	Monthly variation of Ford City natural gas and steam demand	263
3.5	Monthly variation of Ford City natural gas usage	264
4.1	Site layout of existing steam plant and related facilities	267
4.2	Schematic of a gas-turbine based cogeneration system	272
4.3	Schematic of a gas-turbine, combined-cycle cogeneration system	274
5.1	Comparison of residential electricity and natural gas prices from 1974 - 1982	279

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
4.1	Gas Turbine Performance	273
4.2	Gas Turbine System Efficiency	273
5.1	Economic Parameters	281
5.2	Capital Cost of Cogeneration System Options	283
5.3	Real Internal Rate of Return (%) for Ford City Cogeneration Systems	284

Industrial Cogeneration Feasibility Study:
Ford City Commercial/Industrial District

Thomas J. Marciniak and David P. Kuhaneck

ABSTRACT

The Ford City Commercial/Industrial District on the Southwest side of Chicago offers a unique opportunity for the installation of a central cogeneration facility. The site offers a mix of residential, commercial, and industrial occupancies, an existing steam plant with associated steam distribution system and is mostly owned and operated by a single corporation. Also, at this time and for the next several years, electricity rates will be increasing at a rate of about 15 percent per year while natural gas costs are expected to increase at a 10 percent rate.

The electricity demand for the site is about 20-23 MW while the steam demand is about 100,000 lb/h. Using a gas turbine-generator cogeneration system fueled with natural gas, the internal rates of return (IRR) of the project was found to be 25 to 35 percent. Leveraging could increase the return on equity significantly.

Based on this analysis, it is apparent that a cogeneration system at Ford City is both technically and economically feasible. It is recommended that a more detailed design and analysis be performed as a preliminary to project financing and construction.

1.0 INTRODUCTION

1.1 Background

As part of Phase II of the Urban Integrated Industrial Cogeneration Systems Analysis (UIICSA) program conducted by the City of Chicago's Department of Planning, several sites were selected for feasibility analyses of industrial cogeneration applications. The UIICSA program, funded by the United States Department of Energy, has completed its initial phase which included (a) a determination of the industries and sites within the City where cogeneration could be applicable; (b) a review and analysis of the appropriate technologies, energy prices and evaluation methodology for cogeneration systems; (c) a preliminary analysis of environmental impacts if a cogeneration encouraging strategy were pursued; and (d) a market analysis of the overall potential for industrial cogeneration in Chicago. The results of the Phase I effort have been presented in a six volume report issued in 1982 [1.1-1.6].

The first phase of the UIICSA project indicated that a very large technical market exists for industrial cogeneration within the City [1.6]. The total number of economically feasible cogeneration opportunities is much smaller, of course, and is dependent upon several factors. These include the costs of installation, electricity and fuel. Further, whether or not a cogeneration application would be economically attractive depended upon future prices of both electricity and fuel - especially natural gas.

Although several previous analyses of the opportunities for cogeneration in the Midwest have indicated that a limited cogeneration market exists, mainly because of relatively low electricity cost and high priced fuels, [1.7] there are specific areas where the opposite situation exists. Specifically, Chicago and the northern portion of Illinois has been experiencing relatively high electricity prices and rate increases while at the same time the price of natural gas has remained unusually low. The reason for this is two-fold. The electrical utility serving the City is currently financing an expansion program which will result in a one-third increase in capacity while at the same time total electricity demand has been falling at a two percent annual rate since 1978. Meanwhile, due to the existence of long term

contracts for relatively low cost natural gas (and the absence of long term take-or-pay contracts for more expensive supplies, the price of this fuel is not increasing as fast as electricity costs. In fact, in the Midwest, Chicago apparently has the most expensive electricity rates while at the same time natural gas prices are about the lowest. Further, it is expected that although both electricity and fuel prices will both increase significantly over the next five to ten years, the cost of electricity will increase much faster because of the need for capital funds. With these effects in mind, the economic opportunities for cogeneration in Chicago can be expected to be very attractive over the next several years.

Based on more or less purely technical criteria, the UIICS project selected five industrial areas for further study in Phase II. These were judged to have the greatest potential for industrial cogeneration. These are:

- The hospital complex bounded by the Eisenhower Expressway, Damen Avenue, Ashland Avenue and Roosevelt Road. These include Cook County Hospital, the University of Illinois Hospital and Rush-Presbyterian - St. Luke's Hospital and the newly designated high-technology development area;
- The Ford City Shopping and Industrial Center bounded by 67th Street, Cicero Avenue, 77th Street and Pulaski Road;
- The Stockyards area bounded by 35th Street, Western Avenue, 47th Street and Halsted Street;
- The southwest industrial area bounded by Cermak Road, the Chicago City Limits, the Sanitary and Ship Canal and Pulaski Road; and
- The industrial area straddling the Calumet River on the south side between 106th and 127th streets including Republic Steel, Cargill and Interlake.

The main characteristic of each of these areas is that it has a significant industrial energy base. These energy requirements include large amounts of both electricity and steam. Included within each of these sites are one or more manufacturing facilities which could likely support an on-site cogeneration facility itself. Further, each of these sites has the potential for future growth and development which could possibly be encouraged by the availability of an adequate supply of both low cost electricity or steam provided by a central cogeneration facility.

Phase II of the UIICSA project has as its main goal the development of both technical and economic feasibility analyses for at least three of the above sites. Of the five listed above, the selected areas include the Stockyards, the Calumet River area and the Ford City Shopping and Industrial Center. The intent of these studies is to provide sufficient detail in order to form the basis for subsequent detailed designs which could result in the installation of one or more of these systems. These central cogeneration facilities could then serve as part of the efforts to both attract and retain industry within the City by providing low cost steam and electricity. The purpose of this report is to present the results of a preliminary feasibility analysis of the Ford City Shopping and Industrial Center.

1.2 Report Organization

The report is divided into five sections. Section 2.0 is a general description of the site and its surroundings' including an analysis of its advantages and disadvantages as a cogeneration development. Section 3.0 is a review of the current energy requirements for the site including both electricity and thermal demands. Section 4.0 is a brief technical analysis of systems appropriate for the site which Section 5.0 is an economic analysis of the currently most attractive system. Section 6.0 is a summary of the results and includes a list of recommendations which should be considered in any subsequent development.

As with any feasibility study there is uncertainty associated with many of the technical and economic assumptions, used in the analysis. These uncertainties have been addressed as much as possible with the intent of

indicating the most likely values and the effect of possible variations on the results. All in all, indications are that a technically and economically feasible cogeneration project can be designed and installed at Ford City based on gas turbine generators using natural gas as a fuel.

REFERENCES FOR SECTION 1

- 1.1 Project Overview, Phase I Final Report, Urban Integrated Industrial Cogeneration Systems Analysis, City of Chicago Department of Planning, Volume I, December 1982.
- 1.2 Selecting and Evaluating Sites for Integrated Industrial Cogeneration Systems in the City of Chicago, Urban Integrated Industrial Cogeneration Systems Analysis, City of Chicago Department of Planning, Volume 2, March 1982.
- 1.3 Regulatory and Tax Aspects of Cogeneration Development in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis, City of Chicago Department of Planning, Volume 3, December 1982.
- 1.4 Environmental Aspects of Cogeneration Development in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis, City of Chicago Department of Planning, Volume 4, December 1982.
- 1.5 Technology Assessment of Cogeneration and Alternative Fuels in Chicago, Urban Integrated Industrial Cogeneration Systems Analysis, City of Chicago Department of Planning, Volume 5, December 1982.
- 1.6 Industrial Cogeneration Potential in Chicago, 1980 to 2000, Urban Integrated Industrial Cogeneration Systems Analysis, City of Chicago Department of Planning, Volume 6, December 1982.
- 1.7 J. A. Orlando and V. E. Pettit, "Natural Gas Based Cogeneration Market Potential," Gas Research Institute/Argonne National Laboratory Report, March 1982.
- 1.8 The Potential for Industrial Cogeneration Development by 1990, Resource Planning Associates, Inc., Cambridge, Massachusetts, RA-81-1455, July 31, 1981.

2.0 SITE DESCRIPTION

2.1 General

The Ford City Shopping Center and Industrial Park is located in the southwest corner of Chicago on about 450 acres of land. Many of the main buildings on the site (including a steam plant out of service since about 1976) were built in 1942 to house an aircraft engine manufacturing facility. Beginning in the early to mid-1960's, the abandoned plant and site was converted to house a regional shopping center and an industrial park. The site is bounded on the north by a railroad yard while Cicero Avenue, 77th Street (also called Ford City Drive) and Pulaski Road border it on the west, south and east sides, respectively. Both Cicero Avenue and Pulaski Roads are major north-south arteries which provide a link with the Stevenson Expressway approximately four miles to the north. The towns of Bedford Park and Burbank are located just to the west of the site across Cicero Avenue.

Figure 2.1 shows the site and its relationship to major streets and industrial areas within a two mile radius of the existing steam plant. To the north, across the railroad yard, is a small industrial area including the Katalco Chemical plant, Diamond Shamrock and a small electronics firm. Approximately one and a half to two miles north, on the west side of Cicero Avenue, is Midway Airport, including several hangars, administration facilities and the main terminal building. To the east of the site, between Pulaski and Kedzie, is a manufacturing area which includes an area which is part of the Ford City industrial park and at Kedzie Avenue, a Nabisco plant and a Rheem manufacturing facility.

Also, within a two mile radius of the existing steam plant are several other facilities which could be tied into an expanded central steam system. These include the following:

- Scottsdale Shopping Center located at 79th Street and Cicero Avenue;

Fig. 2.1 General location of the Ford City Shopping and Industrial Center.

- Queen of Peace and St. Lawrence High Schools located along 77th Street in Burbank;
- Bogan High School at 79th and Pulaski;
- Von Solbrig Memorial Hospital at 65th and Pulaski;
- Hubbard High School at Hamlin and 63rd Street; and
- Cracker Jack plant at 6600 South Cicero Avenue in Bedford Park.

It should also be noted that a number of manufacturing facilities are located along the south side of 65th street in Bedford Park, between Cicero and Harlem Avenues, which have significant thermal energy demands.

For this particular feasibility study, however, only the Ford City Shopping Center and Industrial Center area located between Cicero and Pulaski will be considered. The reasons for this choice are:

- The site is owned and operated by essentially one corporate entity thus limiting the number of separate decisions usually necessary for such a project;
- There is apparently an adequate electrical and thermal load to justify an economically viable system; and
- Because there are no dedicated streets and the primary business of the potential owners is not generating electricity, it appears likely that there will be no franchise infringement.

2.2 Ford City Shopping Center and Industrial Park

2.2.1 General Considerations

The general site layout of the Ford City Shopping Center, Industrial Center and Industrial Park is shown in Fig. 2.2. As noted above the site is

1 TOOTER ROLL INC.	7 VILLAGE APARTMENTS
2 HOLIDAY INN MOTEL	8 BANK
3 BANK	9 FORD CITY EAST SHOPPING CENTER
4 POWER PLANT	10 KATALCO CHEMICAL CO.
5 UNOCCUPIED	11 DIAMOND SHAMROCK CORP.
6 BANK AND OFFICES	12 ELECTRONICS PLANT

Fig. 2.2 Ford City Shopping Center and Industrial Park.

particularly attractive for the possible installation of a central cogeneration system for several reasons. In addition to the above other favorable characteristics include:

1. A unique blend of residential, commercial, light industrial, and educational facilities that can provide a demand for both electrical power and steam from a cogeneration facility.
2. The existence of a steam plant plus piping distribution system (the condition of which has yet to be determined). The central steam plant was in operation until about 1976 when it was replaced by a distributed system.
3. A significant amount of vacant land and unoccupied space within the Industrial Center which could be used by manufacturing plants with significant amounts of steam requirements (particularly in the food processing industries).

2.2.2 Main Structures and Tenants

The main structures on the site include the Industrial Center, Shopping Center, the General Services Administration (GSA) Warehouse and the Sweetheart Cup Corporation and the Richard J. Daley College. The Industrial Center and the Shopping Center were originally a single structure. Part of the structure was removed to create a parking area and to allow the south portion of the Industrial Center to be used for retail purposes. These include a movie theater plus several stores. The Industrial Center and Shopping Center are connected by two one-hundred-foot-wide tunnels which originally served as utility tunnels and as passages was for workers. Currently about one-half of the east tunnel is used to house retail stores underneath the Shopping Center, parking lot and the front portion of the Industrial Center building.

The Shopping Center is an enclosed mall with about 1.4 million square feet of retail space including the retail portion of the north building. The anchor stores in the complex include J. C. Penny's; Wieboldt's and

Montgomery Ward's. Each store in the complex is metered separately for electrical power, mainly for lighting, while heating and cooling is supplied to the smaller retailers and the common areas by the center operators. Cooling is supplied to the south Shopping Center building by a 1400 ton (16.8×10^6 Btu/h) compressive chiller located on the north side of the building. Heating is supplied by two 500 Bhp (35,400 lb/hr) boilers located with the chiller on the north side of the building plus two 150 Bhp (10,600 lb/hr) boilers located in the west tunnel beneath the parking lot. These boilers supply saturated 15 psig steam to the air handling units located throughout the common areas and in the individual retail stores. Since the major department stores provide their own heating and cooling they are separately metered. Cooling for the retail portion of the north building is generally provided by the tenants, some of whom use roof top units, while heating is supplied, at least in part, by the Center operators from boiler rooms located in the south portion of the Industrial Center building.

Aside from the south portion of the building occupied by retailers, the Ford City Industrial Center is mainly devoted to manufacturing and warehousing. The largest tenant currently in the building is Tootsie Roll Industries, a candy manufacturer. Other occupants include Sweetheart Cup plus a number of small firms ranged along the north side of the building. Much of the building is currently unoccupied. Although Tootsie Roll Industries generates its own process steam, the operators of the Industrial Center provide 15 psig saturated steam from three boiler rooms for space heating. Boiler room number 3 is located in the southwest portion of the building and houses two 400 Bhp boilers with a capacity of 28,340 lb/hr. Boiler room number 4, in the southeast corner of the building has the same capacity while boiler room number 5, located at the north of the building, has two 500 Bhp boilers with a total capacity of 35,430 lb/hr. The total steam generating capacity in the north Industrial and Shopping Centers is approximately 138,170 lb/hr of 15 psig steam. They operate, however, only during the winter months to supply space heat.

The Sweetheart Cup Corporation operates a large manufacturing and warehousing facility directly to the east of the Shopping and Industrial Centers. The facility has an electrical demand that varies between 7000 to

9300 kW and a gas demand that varies between 31.8×10^6 Btu/h in winter to 10.0×10^6 Btu/hr in the summer. The gas usage would translate into approximately 8,000 to 24,000 lb/hr of steam usage if the boilers were 80 percent efficient.

Another large facility on the Ford City site is the General Services Administration Building. This facility, although very large, is only a warehouse and as such has very low requirements for both electricity and thermal energy. An adjacent federally operated facility may provide both a significant electrical and thermal load since it appears to be more an office than a warehouse.

The Ford City site is also home for the campus of Richard J. Daley College, a unit of the Chicago City college system. The College is housed in a four story main building with about 324,000 square feet of space. Also, on the campus are seven one-story buildings with a total area of 78,300 square feet. The main building is completely electric including electric boilers to provide for space heating and has an estimated electrical demand ranging from 1200 kW in the in the winter to about 1600 kW in the summer. The winter heating load, however could easily be accommodated by alternative means - such as steam from the central plant - and would require a maximum of about 1600 lb/hr of steam based on a heating demand of 400 kW.

2.2.3 Other Tenants

Other structures and tenants which, in the aggregate, could provide a significant electrical and thermal load for a central electricity and steam generating facility includes:

- Ford City East Shopping Center;
- Talman Home Banking Facility;
- Village Apartments including two 2-story buildings, four 4-story buildings, one 10-story building, and a recreational facility;

- A 6-story office and bank at the corner of 76th Street and Kostner;
- A 4-story Holiday Inn;
- A U.S. Army Reserve Training Facility;
- A banking facility located to the west of the Shopping Center;
- A structure, formerly occupied by a bakery, but currently used as a warehouse to the south of the steam plant;
- A warehouse west of the Industrial Center; and
- A former engine test facility located just to the north of the Industrial Center which currently is home to several small manufacturers.

2.3 Vacant Land

The north portion of the Ford City property is zoned for motor freight facilities and is currently used as such. If the proposed central cogeneration facility were successful in providing both low cost electricity and steam to manufacturing firms, it may be necessary to change the zoning to accommodate new process plants that could use low cost steam. If this were done, along with the already vacant land on the site, approximately 140 acres of land could be made available for industrial development along with the unoccupied portion of the Industrial Center.

A central cogeneration facility could conceivably attract industries, especially in the food processing industries, which have requirements for process steam. This would occur because the load already on-site is for the most part electrical thus indicating that a surplus of steam will be produced. Preliminary indications are that the match is fairly close provided that changes can be made in the end-use technologies on the site. For

example, the steam load could be maintained throughout the summer if the compressive chillers were replaced by similarly sized absorptive chillers throughout the site. More will be said about these possibilities in subsequent sections.

3.0 SITE ENERGY REQUIREMENTS

3.1 General

The total site electrical and thermal energy requirements were difficult to determine because of a lack of data for many of the buildings and tenants. Monthly data for electricity, natural gas and steam output were available from some of the major on-site users, such as Tootsie Roll, Sweetheart Cup and Harry F. Chaddick Realty Company, the operators of the complex. The rest of the energy loads were estimated from the total area of the facility and the average energy required per unit area. A more detailed energy analysis is required in order to precisely size the cogeneration facility and estimate daily, seasonal and annual energy use patterns and requirements on a site-wide basis. Despite these more obvious limitations of the study, it is felt that the energy requirements used are at least in the "ballpark" of the total site-wide energy demands and that these estimates are likely to be less than the actual demands.

3.2 Electricity Requirements

Potentially the easiest energy use statistics to obtain are the electrical energy use patterns for each of the Ford City tenants. Major users such as Harry F. Chaddick Realty, Inc., Tootsie Roll Industries and Sweetheart Cup provided adequate data for their operators. The electrical energy use for the rest of the site was estimated based on the area of the structures and a knowledge of the type of energy system in the building. However, only the major energy users were included in the estimates. These included the smaller retailers in the Shopping Center, the major retailers, the common areas in both the Industrial Center and the Shopping Center, the GSA Warehouse, and the Daley College main building. No estimates of the electrical energy usage in other occupancies were made. In the aggregate this could be substantial since it would include the Village Apartments, Holiday Inn, two banks an office building plus numerous smaller stand-alone buildings on the site including the motor freight terminals. These could add as much as another twenty percent to the total electrical load.

The one consideration that must be taken into account is to separate heating, ventilating and air conditioning (HVAC) loads from non-HVAC loads. The non-HVAC loads essentially include lighting, elevators, escalators or any other usage not associated with HVAC needs. However, fans and pumps were included in the non-HVAC loads considered here because these systems would continue to operate in their current manner even if the way in which heating and air conditioning were supplied were changed. HVAC electrical loads were those associated with electric compressive chillers and electric heating.

The average total electric demand on the site as it varies throughout the year is shown in Fig. 3.1. In this figure the non-HVAC and HVAC electrical loads are separated. As can be seen in this estimate, the HVAC electrical load is essentially due to air conditioning requirements from April through October of each year. The air conditioning load, which reaches a peak of about 2700 kW in August, could theoretically be met by absorption chillers using roughly 65,000 lb/h of 15 psig steam. Thus, the electrical generating capacity could be reduced and the steam utilization improved for the central cogeneration facility.

The total peak electrical demand has been estimated to be 21,900 kW. If the load associated with the buildings not used in the estimate is included the peak load could be as high as 26,300 kW with the peak occurring in the summer. The non-HVAC load ranges as high as 19,200 kW and considering a 20 percent add on the total on-site non-HVAC load could be as high as 23,000 kW. It should be kept in mind that these demands are based on what is currently on the site and does not include any estimates for additional occupancy of the Industrial Center or other buildings on the site.

The total electrical energy use per month is shown in Fig. 3.2. The peak energy requirement is about 10.3 million kWh which occurs in July or August of each year. The total annual energy usage is about 101.7 million kWh, which at an average rate of 7.562 \$/kWh (the average electrical energy cost to small commercial and industrial users in 1982) would cost about \$7.7 million per year. Considering a twenty percent additional load due to other buildings, then 122 million kWh would be used at a cost of about \$9.23 million.

Fig. 3.1 Annual variation of Ford City total and non-HVAC electricity demand.

Fig. 3.2 Annual variation of total electrical usage.

The load factor for the system as it varies from month to month is shown in Fig. 3.3. On a month-by-month basis the load factor varies from a low of about 0.57 in December to a high of 0.74 in February. The average load factor over the year is 0.53 based in a peak of 21,900 kW. If only the non-HVAC loads are considered the yearly average load factor is about 0.58 and could be higher if more of the non-HVAC load could be taken up by a thermal means.

In summary, the electrical demand for the Ford City site could range as high as about 23,000 to 26,000 kW with an annual load factor of 0.58 to 0.7. These values will be used as a basis in the system design evaluations to follow.

3.3 Thermal Energy Requirements

Estimating the thermal energy requirements of the Ford City Shopping and Industrial Center was somewhat more difficult than determining the electrical energy requirements. Natural gas requirements for Tootsie Roll, Sweetheart Cup, the five boiler rooms in the Shopping and Industrial Center plus the GSA building were given. The natural gas used on the site is used to generate low pressure saturated steam for space heating and process needs. Low pressure systems are used in order to be able to use automatically controlled boiler rooms not requiring the presence of a stationary engineer.

Figure 3.4 shows the month-by-month average hourly natural gas demand for the site. This ranges from a high of 113 million Btu/h in January to a low of about 25 million Btu/h in the summer. If the boilers are assumed to be about 80 percent efficient and steam is produced at 15 psig (30 psia) then these amounts of gas usage would translate into steam demands ranging from a high of 95,000 lb/hr in January to a low of 23,000 lb/hr in the summer.

Total gas usage on a monthly basis is shown in Fig. 3.5. This ranges from a high of about 826,000 therms ($82,600 \times 10^6$ Btu) in January to a low of about 190,800 therms ($19,080 \times 10^6$ Btu) in July. These amounts of natural gas usage correspond to about 69.9 million pounds of steam in January to 16.2 million pounds in July. The totals of annual natural gas and steam

Fig. 3.3 Annual load factor variation at Ford City.

Fig. 3.4 Monthly variation of Ford City natural gas and steam demand.

Fig. 3.5 Monthly variation of Furd City natural gas usage.

used on the site are 4.719 million therms and 399.5 million pounds of steam. Assuming natural gas to cost \$5.46/10⁶ Btu the total annual cost is \$2.577 million while the cost of steam would be \$3.22 million based on fuel costs alone.

In designing a cogeneration plant for this site, consideration will be given first to covering the electrical demand. The steam produced from recovered waste heat should cover the current on-site demand and also allow for conversion of some amount of electrically provided HVAC services (i.e., heating and cooling) to steam. For the designs in the following section, each system will be considered to operate with an electrical and steam load factor of 0.65 under the assumption that these loads will match throughout the year. Of course, this is probably not true in reality, but the system designs (including both electrical to steam production ratios and installed costs per kW of generating capacity) will not vary much and will thus have little effect on the economic returns for the projects.

4.0 SYSTEM DESIGN

4.1 General

One of the advantages of the Ford City Shopping and Industrial Center area is the fact that a steam plant exists on the site along with a steam distribution system. The steam plant was originally constructed in 1942 along with the rest of the aircraft engine manufacturing facility, and was in operation until about 1976. In that year the steam plant was decommissioned in favor of five smaller boiler rooms which serve only the space heating needs of the Shopping Center and Industrial Center buildings. The total capacity of the ten boilers is about 138,200 lb/h of 15 psig steam (250°F) which is used only for winter time space heating.

The original steam plant had four boilers each supplying steam at 175 psig. Although the drawings for the boiler house were not reviewed, it is estimated that the total capacity of the plant was about 400,000 lb/h. Two of the boilers were fueled with coal while the third used oil and the fourth used either natural gas or oil. At the time the plant was closed down, only two of the boilers were in operation and these were apparently run only during the winter months. The move to the dispersed boiler room system was economically justified because of reduced operating expenses. The original steam plant was, in the broadest sense, a cogeneration facility in that although it did not produce electrical power, it did produce compressed air which was distributed around the site.

The site layout of the power plant is shown in Fig. 4.1. The main building is of brick construction approximately 90 feet high in the boiler bay which is about 62 feet wide by 200 feet long. To the west a machinery bay roughly 38 feet wide by 200 feet long housed several steam driven compressors - all, but one, now removed. On the south a bay 60 feet wide by 80 feet long apparently housed an incinerator at one time but is now used only by a manufacturing tenant. Adjacent to the main boiler house is a one story building which was apparently an office but is now used by a motor freight company.

Fig. 4.1 Site layout of existing steam plant and related facilities.

The current facility, although in disuse, could likely house a new central cogeneration system. However, given the condition of the mechanical equipment and the fact that two of the boilers were originally coal-fueled, it is not likely that this equipment can be used in a new system. This option should be evaluated but it does not appear at this time to be feasible.

Thus, it is suggested that the existing steam plant buildings and facilities be used as the site of a new cogeneration facility. The advantages for using the existing plant are:

1. It avoids the cost of acquiring new land for a facility, the construction of new buildings and the accessing the existing steam tunnels on site.
2. The boiler house is next to Commonwealth Edison's transformer yard which serves Ford City, thus making the interconnection with the utility easier.
3. The boiler house is already served by other important utilities such as natural gas and water.
4. Adequate space exists within and around the building to house the generating equipment, waste heat boilers and ancillary equipment for a relatively large cogeneration facility that could serve a much larger area in the future.

4.2 System Technological Options

The power generation technologies which are currently available for use in on-site cogeneration facilities include:

1. steam turbines,
2. diesel engines, and
3. gas turbines.

Each of these have both advantages and disadvantages for the Ford City site. These will be considered in the following.

4.2.1 Steam Turbine Systems

Steam turbine systems offer the advantage of fuel flexibility. For example, the steam boilers in the existing steam plant used coal, oil or natural gas. However, steam systems, especially those using back pressure turbines, are usually relatively inefficient ($< 20\%$) and are most appropriate in cogeneration applications which have a high thermal to electrical energy ratio [4.1]. The Ford City site, unfortunately, has just the opposite characteristic, thus indicating that such a system may not be the most appropriate choice either economically or technically.

Although steam turbine systems do have fuel flexibility, in the case of the Ford City site it is likely that the only fuels which would be economically feasible would be oil or gas. The use of coal would likely be prohibitive because of the added initial capital cost for coal handling facilities and environmental central equipment. Also, the availabilities of oil or gas fired boiler/steam turbine systems are somewhat lower than comparably-sized gas turbines or diesels.

Thus, because fired boiler steam turbines have high thermal to electrical output ratios, low thermal efficiency relatively low availability and high capital cost they were eliminated from further consideration at this time.

4.2.2 Diesel Engine Systems

Diesel engine based systems are attractive for cogeneration systems because of their relatively high thermal efficiency for producing electricity, moderate capital cost and operational flexibility. Disadvantages generally are environmentally related. For example, they generally are somewhat noisy and have high NO_x , particulate and hydrocarbon emissions. The fuel flexibility of diesel engines allows them to be operated on natural gas and #2 through

#6 oil. Some engines are designed to have dual fuel capability and can easily be switched from natural gas to #2 oil operation, for example.

Diesel engines could be quite attractive as a technological option for the Ford City site. They have full load efficiencies of about 35 percent and can use natural gas as a fuel. Larger engines can be switched between #6 and natural gas - two fuels which are considered to be direct competitors in the industrial fuels market. The capital cost is of a diesel system roughly equivalent to a gas turbine system in the 10,000 kW size.

For the Ford City site diesel engines were not selected mainly because of questions about their environmental characteristics. However, with their higher efficiency and similar capital costs, they would be, most likely, a somewhat better economic choice than gas turbines. As such, diesel engines should be considered again if a more detailed design study is performed in Phase III of the UIICSA project.

4.2.3 Gas Turbine Systems

Gas turbines have been used extensively in relatively medium to large cogeneration systems where natural gas is readily available. Large gas turbine cogeneration systems serve the Naval Training Facility in San Diego and a four unit, 300 MW system will be built soon in Texas. Also, a new gas turbine cogeneration system was installed at a synthetic natural gas production facility near Morris, Illinois. Gas turbines also are used extensively on interstate natural gas pipeline systems to power compressors. Thus, there is an extensive amount of experience with these engines in situations where their reliable operation is required.

Simple cycle gas turbines have efficiencies in the range of about 27 to 30 percent. Depending upon the excess air used, exhaust gas temperatures could be as high as 1000°F, although 750°F to 900°F is common. These high temperatures can permit the use of bottoming cycle systems which can boost overall electrical efficiency as high as 40 percent in some cases. In larger sizes, greater than 10 MW, gas turbines are generally cheaper to install per kW of capacity than any other system. This capital cost saving is usually

enough to offset the lower operating efficiency and higher fuel costs associated with their operation.

For the Ford City central cogeneration facility a gas turbine system was selected as the basis for a technical and economic feasibility analysis. The initial capital cost would be comparable to a diesel system but fuel costs would be somewhat higher due to lower electrical generation efficiency. It is expected that the overall costs associated with each system would be roughly equivalent.

4.3 Ford City Cogeneration System

The system selected for the Ford City central cogeneration system is based on a gas turbine-generator set. The specific model selected on this study was the Mars engine produced by the Solar Turbine Division of the Caterpillar Company. This engine-generator set, nominally rated at 7200 kW, has been used extensively in industrial power and cogeneration systems and is fairly typical of the state-of-the-art.

A schematic of the Mars turbine generator set is shown in Fig. 4.2. This unit can produce about 6950 kW of power while generating 30,085 lb/h of steam at 15 psig and 350°F. This is roughly the equivalent of one-fourth of the peak capacity required at the Ford City site for both electricity and steam. Each gas turbine consumes about 80.3 MMBtu/h of natural gas for an electrical efficiency of about 28.6 percent. The overall efficiency of the unit, including a heat recovery efficiency of about 44.3 percent, is about 73.8 percent. Table 4.1 shows the fuel requirements, power output and heat recovery potential for these units at full power and at 75 percent and 50 percent full power, respectively. Table 4.2 shows the electrical and heat recovery efficiency of the plant at these power levels.

Fig. 4.2 Schematic of a gas-turbine based cogeneration system.

Table 4.1
GAS TURBINE PERFORMANCE

Fuel Flow (MMBtu/h)	Power (kW)	Exhaust Gas		Heat Recovered* (MMBtu/h)
		Temperature (°F)	Flow (1000 lb/h)	
80.3	6950	768	304	35.6
65.3	5210	707	207	27.6
52.7	3475	680	243	23.1

*Assumes a 300°F exit temperature.

Table 4.2
GAS TURBINE SYSTEM EFFICIENCY

Power (%)	Elect. Eff. η_e (%)	Heat Recovery Eff. η_{HR} (%)	Total Eff. η_T (%)
100	29.5	44.3	73.8
75	27.2	42.2	69.4
50	22.5	43.8	66.3

An alternative gas turbine system uses a steam turbine bottoming engine to generate additional power. This system, shown in Fig. 4.3, is especially appropriate if the thermal to electrical energy ratio is low or if operations require trade-offs between electrical and thermal energy outputs. With a steam turbine bottoming cycle the electrical energy is boosted to almost 8100 kW and the net electrical efficiency becomes 34.4 percent since no additional fuel is required. The usable steam, however, is decreased by 12.8 percent so that the overall efficiency of the plant becomes 73.0 percent, or roughly the same as it was previously. Thus, with a capital cost increase it is possible to design a gas turbine combined cycle system which may match the

Fig. 4.3. Schematic of a gas-turbine, combined-cycle cogeneration system.

requirements of the site more closely. However, this approach was not considered in the economic analysis which follows in the next section.

REFERENCE FOR SECTION 4

- 4.1 R. W. Porter, "Technology Assessment of Cogeneration and Alternative Fuels in Chicago," UIICSA Phase I Report, Volume 5, December 1982.

5.0 ECONOMIC EVALUATION

5.1 General

It has been pointed out repeatedly over the years that cogeneration systems will save energy. This premise has been used to justify a group of laws and exceptions to laws over the past few years, all designed to encourage cogeneration. Perhaps the most important of these measures is the Public Utility Regulatory Policy Act (PURPA) of 1978. This Act was intended to overcome two of the more vexing problems associated with limiting the widespread use of cogeneration. Those problems were (1) the connection of the cogeneration facility to the local utility grid and (2) the payment of a fair rate, based on the utility's avoided cost, for the power generated by the cogeneration facility.

The first issue was really never a problem with larger systems, but was a factor in limiting the installation of smaller systems. The second point was intended to resolve an impasse which was based on the idea that in an area where electricity demand was increasing, the marginal cost of the next kilowatt of capacity was less if it were a cogenerated kilowatt rather than a central station kilowatt. Thus it was expected that a given cogeneration facility would be paid more for its electricity than it would cost to generate it and the other utility customers would benefit because that amount would be less than the amount that would have otherwise been charged. Everyone was expected to be a winner. Energy would be conserved and electricity prices would be less.

5.1.1 Electricity Costs

In practice, however, the avoided cost paid to cogenerators (and other small power producers) has not been very much more than the cost paid. In fact in many areas, such as Chicago, it has been less. For example, in the Chicago area a small industrial or commercial customer using 200,000 kWh per month with a peak demand of 500 kW would pay, on average, 6.55 ¢/kWh before

any taxes are assessed*. If this facility were to generate electricity equal to its use and demand level, the avoided cost paid would range from a high of 5.31 ¢/kWh during peak periods in the summer to a low of 2.90 ¢/kWh for off-peak hours in the summer. Hardly the kind of rates that would encourage cogeneration.

The reason for this is that the local electric utility is currently adding over 6000 MW of capacity to its system which will result in a high reserve margin by 1988. There is no reason for an allowance for avoided capacity expenditures to cogeneration. Clearly if an industrial facility could generate electricity, it would only generate enough to cover its now needs but would not likely sell to the grid unless its marginal cost to do so is less than the buyback rate - an unlikely condition. Thus, it appears that a cogeneration facility in Chicago would only generate enough power to avoid purchases from the local electrical utility. If this cost is high enough, and the cost of fuel is low enough, then a cogeneration facility will be installed in order to reduce the costs of energy for an end user.

In the most recent year for which data is available, 1982, the average cost of electricity to small industrial and commercial customers was 7.572 ¢/kWh [5.1]. This represents a 12.5 percent increase over the average rate charged in 1981 and is roughly 7 to 8 percent higher than the inflation rate for the year [5.2]. With new rates approved in December, 1982 (and a rate increase asked for in October, 1983) the escalation pace for electricity can be expected to maintain or exceed this rate for the next few years - at least until the current construction program is completed.

5.1.2 Fuel Costs

Fuel prices in Chicago, on the other hand, have a tendency to be low - especially for natural gas. Excluding taxes, the price of natural gas to an industrial customer using more than 20 MMBtu/h is \$4.829/MMBtu [5.3]. If the gas is used for power production the cost is \$4.379/MMBtu. This latter

*It should be noted that the monthly bill for such a customer in Chicago is the eighth highest out of 84 cities listed in the Energy User News of October 24, 1983.

cost for natural gas is low enough to make a cogeneration facility an economically attractive proposition even if the tax of 13.74 percent is considered. Thus the only problem left to consider is the future expectations of these prices specifically oriented to Chicago's market.

5.1.3 Future Cost Expectations

There are two truisms to consider when making predictions about future energy prices. The first is that energy prices will increase. The second is that any attempt to predict those increases will be wrong but it never stops anyone from making the attempt.

Figure 5.1 shows a comparison of natural gas and electricity price increases since 1974 in the residential sector in Cook County. All of these costs have been normalized to 1.0 for the average price of natural gas in 1974. This year was selected for two reasons. First it was the first full year of the "energy crises" and, secondly it roughly coincides with the start of Commonwealth Edison's construction program. Thus we should see the worst of both worlds.

Since 1974 the cost of natural gas has increased at a rate of roughly 14 percent per year while the price of electricity increased by 11 percent per year. The ratio of electricity to natural gas prices (using \$/MMBtu) decreased from 7.52 to 6.108 during that time. However, more recent history shows increases in electricity of about 14-15 percent while natural gas prices increased about 9 percent. In real terms this would correspond to about 10 percent for electricity and 4 percent for natural gas.

Future expectations of electricity prices for the Chicago area are for increases in the range of 15 percent until about 1988 (5 years) when the current construction program is completed. Thereafter, electricity prices are expected to remain constant, in real terms, through at least the end of the century. This scenario seems fairly certain for the period through 1988 given the financial requirements of Commonwealth Edison but beyond that time it is much more difficult to predict.

Fig. 5.1 Comparison of residential electricity and natural gas prices from 1974 - 1982.

On the other hand, natural gas prices in the future are somewhat more uncertain mainly because of regulation. Natural gas prices in Chicago and the northern portion of Illinois are relatively low compared to the rest of the Midwest and the nation. The reason for this is that the local gas utilities have long term contracts for relatively inexpensive natural gas and they are not saddled with take-or-pay contracts for expensive gas. However, natural gas deregulation looms on the horizon and expectations are that prices will increase dramatically. This is the conventional wisdom despite recent deregulation of oil prices. In any event, the American Gas Association expects average natural gas prices to increase by about 2.5 percent per year over the period from 1982 - 1992 on a national basis [5.4]. Allowing for Chicago's currently low price, we will assume that natural gas prices will increase at a 4 percent clip (in real terms) per year over the next ten years and substantially level off after that time.

5.2 Economic Assumptions

One of the problems that must be considered when doing an economic analysis of a cogeneration facility is the uncertainty attached to many economic assumptions. In performing the economic analysis for the Ford City cogeneration system, energy prices in effect in mid-1983 were used as a basis. All inflation rates were assumed to be in real terms so that all results (listed in detail in Appendix A) are in 1983 dollars. Similarly, all internal rates of return are calculated in real terms and should be adjusted for inflation as needed.

Three separate cases were addressed in this analysis. The economic parameters for each case are shown in Table 5.1. Case B may be considered the base case while Case A assumes that natural gas will not inflate over the life of the plant (20 years). Both Cases A and B assume that a 10 percent investment tax credit is allowed and that the entire installed plant is considered to be 5 year depreciable property which, under ACRS rules, can be depreciated according to a schedule of 15, 22, 21, 21, and 21 percent per year. Case C, on the other hand, is the same as Case B, except that there is no tax credit and depreciation takes place over 15 years using a sum-of-the-years digits (SYD) schedule. This last would represent a more conventional economic

Table 5.1

ECONOMIC PARAMETERS

	Case		
	A	B	C
Avg. Electricity Cost (¢/kWh)	7.5	7.5	7.5
Avg. Natural Gas Cost (\$/MMBtu)	4.90	4.90	4.90
Avg. Steam Cost (\$/1000 lb)	8.0	8.0	8.0
Operation and Maintenance (¢/kWh)	1.0	1.0	1.0
Tax Rate (%)	48	48	48
Tax Credit (%)	10	10	10
Depreciation Schedule	ACRS	ACRS	SYD
Property Tax and Ins. (%)	0.9	0.9	0.9
Depreciable Life (Years)	5	5	15
System Life (Years)	20	20	20
Real Inflation Rates (%/yr)			
Natural Gas/Steam	0	4	4
Electricity	6	10	10
Inflation Terms (yrs)			
Natural Gas/Steam	0	10	10
Electricity	5	5	5

analysis approach which indicates some of the effects of special treatment for similar investments. No energy tax credit is considered.

Table 5.2 shows the capital costs of two different systems using two different sets of assumptions about the capital cost of the system. Options 1 and 2 are based on installing four gas turbine-generators will all anullary equipment using either \$1100/kW or \$655/kW as its installation cost. The cost of \$1100/kW is from Porter [5.5] while that of \$655/kW was based on data received from the manufacturer concerning recent installations [5.6]. Options, 3 and 4 are based on the idea that the same engines used in 1 and 2 have been rerated from 7200 kW to 8800 kW (at standard conditions) and are installed for the same price per engine-generator set. The effect, of course, is to decrease the \$/kW cost of the equipment.

In all cases the piping distribution system, power plant rehabilitation and end user retrofit costs are assumed to be the same, totaling \$6,752,000. End user retrofit costs are quite difficult to estimate without a more detailed knowledge of the site, but in any case, it appears that doubling, or even tripling this cost will not have a strong effect on the internal rate of return of the project.

From Table 5.2 it is seen that the total installed cost of a co-generation system at the Ford City site can range from a low of \$877/kW to a high of \$1,477. Generally, this seems to bracket the capital costs normally encountered for such systems. The capital costs at the Ford City site should have a tendency to be on the low side because of (a) the existing steam plant building and associated piping distribution system and (b) a relatively compact site serving a diverse group of potential customers.

5.3 Results

The detailed results for each of the twelve combinations of capital cost options and economic cases are given in Appendix A. Table 5.3 shows the results of these calculations in terms of the Real Internal Rate of Return (RIRR) for each project.

Table 5.2

CAPITAL COST OF COGENERATION SYSTEM OPTIONS

	System Option			
	1	2	3	4
No. Gas. Turbine Gen. Sets	4	4	3	3
Elect. Output/Unit (kW)	6,950	6,950	8,530	8,533
System Capacity (kW)	27,800	27,800	25,600	25,600
Cost/kW (\$/kW)*	1,100	655	896	533
Gas Turbine-Generator Cost* (\$1,000)	30,580	18,209	22,935	13,657
Steam Dist. System (15,840 @ \$300/ft) (\$1,000)	4,752	4,752	4,752	4,752
Power Plant Rehabilitation (\$1,000)	1,000	1,000	1,000	1,000
End User Retrofit (\$1,000)	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>
SUBTOTAL (\$1,000)	37,332	24,961	29,687	20,409
CONTINGENCY (10%) (\$1,000)	<u>3,733</u>	<u>2,496</u>	<u>2,969</u>	<u>2,041</u>
TOTAL CAPITAL COST (\$1,000)	41,065	27,457	32,656	22,450
COST (\$/kW)	1,477	988	1,276	877

*Includes gas turbine, generator, waste heat boiler, controls, gas compressor and interconnection switch gear.

Table 5.3

REAL INTERNAL RATE OF RETURN (%) FOR FORD CITY COGENERATION SYSTEMS

Economic Case	System Option			
	1	2	3	4
A	17.5	24.4	21.0	27.5
B	19.6	26.6	22.5	29.9
C	16.1	22.7	18.9	25.8

For the base economic parameter assumptions given in Case B, the RIRR ranges from a low of 19.6 percent to a high of 29.9 percent. Considering more recent inflation rates of approximately 4-5 percent, the IRR would range from about 25 percent to 35.8 percent. Under the slightly more conservative rates assumed under Case A for the four options, the RIRR ranges from 17.5 percent to 27.5 percent. This is roughly comparable to the Case B results.

By ignoring any tax credits and the greatly accelerated ACRS depreciation schedules, the RIRR for each option under Case C assumptions is not strongly affected. The RIRR ranges from a low of 16.1 percent to a high of 25.8 percent. These correspond to inflation adjusted internal rates of return ranging from 21.3 percent to 31.5 percent.

It should be kept in mind that these results ignore any leveraging effects due to debt. It is clear that if a significant amount of debt were used to finance the initial investment the rate of return based on equity would increase substantially. These results, then, represent the minimum RIRR assuming that all of the capital cost is equity funded.

How do these rates compare to those experienced elsewhere? Currently (October, 1983) the prime lending rate is about 11 percent representing a real rate of 6-7 percent. Last year (1982) the rate of return on equity for several investor owned utilities was approximately 12-15 percent and about 5-6 percent on total assets. Adjusting these returns for inflation, in real terms, range from 8-11 percent based on equity and 1 to 2 percent on total assets. For Commonwealth Edison the return on common equity was 13 percent while the return on total assets was about 4 percent.

In summary, based on the capital cost and economic parameters assumed, the real rates of return on total assets would be quite attractive for many investors. The soft parts of the analysis are, at this point, the average selling price (or avoided cost) per kWh of electricity for Ford City tenants (assumed to be 7.5 ¢/kWh) and the value of steam (assumed to be \$8/1000 lb). The actual values used would be dependent upon the current tenant size and mix and the technologies and fuels actually used to generate steam on site.

This analysis, too, does not consider alternatives. For example, a site-wide energy management system may prove advantageous. Or, HVAC technological changes may in some cases be more beneficial. This analysis does, however, indicate that centralized cogeneration facility at Ford City could be an economically attractive investment if (a) capital costs can be limited to under \$1500 per installed electrical kilowatt and (b) energy price increases follow a pattern for at least the next five years similar to those of the last two years.

REFERENCES FOR SECTION 5

- 5.1 Commonwealth Edison: 1982 Annual Report.
- 5.2 Commonwealth Edison: 1981 Annual Report.
- 5.3 Marketing Department, People's Light, Gas and Coke Company, Chicago, Illinois, September, 1983.
- 5.4 Analysis of National Average Natural Gas Prices: 1983 Update, American Gas Association, Arlington, Virginia, February 18, 1983.
- 5.5 R. W. Porter, "Technology Assessment of Cogeneration and Alternative Fuels in Chicago," Volume 5 UIICSA Phase 1 Report, December, 1982.
- 5.6 Robert M. Keller, Solar Turbines International, Private Communication, September 26, 1983.

6.0 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Results Summary

This report is focused on the results of a feasibility analysis of a cogeneration system located at the Ford City Shopping and Industrial Center in Chicago. The site is fundamentally attractive for a number of reasons. The more important include:

- a. A relatively large electrical load (> 20,000 kW) provided by a diversity of firms, buildings, and tenants in the residential, commercial, and industrial sectors.
- b. A history of central steam plant operation (until 1976) with an existing steam plant, on-site electrical utility transformer yard and in-place steam distribution system.
- c. Location in an area where the basic cogeneration facility could be expanded either by encouraging industrial development on-site or by connecting to nearby industrial, educational, commercial or medical facilities.

In summary, the site itself has inherent qualities which indicate that a centralized cogeneration facility would be not only technically, but economically, feasible.

Currently the Chicago area offers a unique opportunity for cogeneration development because of local electrical and natural gas prices. Over the past three or four years electrical rates have been increasing at a 12-15 percent per year clip. At the present time, the average cost of electricity to a medium sized industrial firm with a less than 750 kW demand is about 7.5 ¢/kWh. This represents the highest cost among almost a dozen cities located in states bordering Illinois according to recently published data. These rates put Chicago in the "costly" range of electricity rates to industrial users. On the other hand, natural gas prices in the Chicago area, especially rates published for power production, are among the lowest in the nation

because of long term contracts for low-priced gas held by the local utility. The price spread between electricity and natural gas is now about \$16.80/MMBtu suggesting that a moderately priced cogeneration system would be economically attractive.

In the near future (about 5 years), electricity prices are expected to increase at a rate varying from 15 to 20 percent per year as the local electric utility tries to raise enough money to complete a nuclear based generating capacity increase of over 6,600 MW. This will increase system capacity by almost one-third. Unfortunately, from 1978 through 1982, total electricity usage has been falling at a rate of about 2 percent per year which suggests that the system will have a capacity margin of about 35 to 40 percent. It is expected, however, that electricity prices will stabilize once the construction program is completed since more stable fuels such as coal and uranium will dominate.

Data suggest that if the above scenario is true, the real price of electricity will inflate at a rate of 10 percent per year over the next five years. Natural gas prices, however, will increase at a rate of 4 percent per year, in real terms, based on both recent experience and projections by the American Gas Association. This price escalation differential suggests that for the next several years cogeneration, or on-site generation of electrical energy, may prove to be advantageous. After 1988, however, the picture becomes somewhat muddled.

An initial estimate of the total energy demand and usage at the Ford City site indicates that electricity demand could be as high as 23,000 kW while the steam demand is about 95,000 to over 100,000 lb/h. The load factor for the system ranges from 0.57 to about 0.70.

The most desirable fuel for a cogeneration facility at Ford City appears to be natural gas. This is due to its relatively low price, lower cost of capital equipment (compared to coal, for example) and its low environmental impact. Number 6 oil, it should be noted, would be priced competitively with natural gas since it is an alternative industrial fuel and should be considered in a final system design.

The capital cost for a gas turbine based cogeneration system at Ford City would range from \$23 million to \$41 million, or \$877/kW to \$1,477/kW including the steam distribution system. With these capital costs and assuming a 10 percent real inflation rate for electricity over the next five years and a 4 percent rate for natural gas, real rates of return on the investment would range from 19.6 percent to 29.9 percent. Adjusted for an inflation rate of 4.5 percent, the rates of return would be 25 percent and 35.7 percent, respectively. If tax credits as well as the 5 year ACRS depreciation schedule were eliminated, then the real rates of return will range from 16.1 percent to 25.8 percent.

These rates of return are quite attractive compared to the current prime rate (11 percent) and the return on equity for manufacturing facilities and public, investor-owned utilities (about 15 percent). They can be made much more attractive with a suitable amount of debt provided by a mix of industrial development bonds, mortgages or other financial instruments. What is important, however, is that the project appears to be financially viable in its own right.

6.2 Conclusions

With a real rate of return on the total investment ranging from 19.6 to 29.9 percent, a cogeneration facility at the Ford City Shopping and Industrial Center appears to be an attractive investment. However, the attractiveness of the investment is highly dependent upon the prices of natural gas and electricity over the next five to ten years. Current expectations are that electricity prices will increase at a faster rate than natural gas prices over the next five years. Thereafter, natural gas prices are expected to increase at a real rate about 4 percent faster than electricity over the following five years. This would indicate that a relatively narrow window exists over the next five years for economically attractive cogeneration systems in Chicago.

Aside from the uncertainty inherent in estimates of future energy prices, there is also uncertainty associated with the total cost of the cogeneration system and its capacity. For a system to have an attractive rate of return in Chicago it appears that the maximum cost per kilowatt is about

\$1500/kW for a load factor of about 0.65. This amount would be higher if the load factor is increased. Conversely, the allowed capital cost would be lower if the load factor would decrease. Also, it appears that the cost per kilowatt would be relatively insensitive to system size provided that it was over about 14-16,000 kW since no credit was taken in this analysis for economics of scale associated with multiple unit installations.

A steam load already exists on the site for both industrial process needs and space heating requirements. However, this load is strongly tilted toward the winter and attempts should be made to shift it at a level comparable to the annual electric load variation. This can be done in two ways. First, additional industrial process steam demands could be added by (a) encouraging new tenants on the site or (b) by adding off-site steam users such as the Katalco and Diamond Shamrock plants located north of the site. Secondly, changes could be made in the cooling system to shift from electrically driven compressive chillers to steam using absorptive chillers. This would have a tendency to increase summer steam demands which are currently non-existent for HVAC requirements.

The fundamental conclusion of this analysis is that it appears that an economically viable cogeneration system can be installed at the Ford City site. Uncertainties associated with future energy costs and capital costs can be reduced by a more detailed design study to serve as the basis for proceeding to construction.

6.3 Recommendations

This preliminary feasibility analysis has indicated that a technically and economically viable cogeneration project can be designed and installed at the Ford City site. However, prior to attempting to finance and construct the system it is recommended that a detailed system design and analysis be undertaken to resolve several issues. These include:

1. A detailed energy analysis of the site, including a determination of the daily, seasonal and annual electrical and steam demand patterns.

2. A detailed central cogeneration plant design optimized for the site is required. Although a gas turbine system fueled with natural gas was selected, alternatives should be evaluated. These include systems fueled with coal, oil or urban refuse and systems based on either diesel engines or steam turbines. It may well be that other options may prove more economically attractive.
3. An evaluation should be made of the HVAC systems on-site to determine the best mix between electrically or thermally provided space heating and cooling needs. For example, the Daley College uses electric boilers for heating, the Shopping Center uses a 1400 ton compressive chiller for cooling and the Village Apartments are all electric. Consideration should be given to changing these systems to be more compatible with a cogeneration system.
4. A more thorough analysis should be undertaken regarding future electricity and fuel prices since these are crucial to the financial viability of the project. Consideration should be given to long term contracts with tenants as well as suppliers to reduce the risk.
5. Consideration should be given to alternative ownership strategies. Currently the most obvious owner and operator of the system is the firm responsible for Ford City operations. Alternatives would include either electric or gas utility ownership or a third party organization. The firms which operates the facility should be large enough to use the tax savings which accrue in the early years of the project.
6. Consideration should be given to encouraging industrial development on the Ford City site by providing low cost energy in the form of electricity or process steam. Firms in the food processing industries seem to be the most likely candidates.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

APPENDIX A
Cogeneration System Economic Analysis

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Table A.1

CASE 1A: FORD CITY ECONOMIC ANALYSIS

(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	41,065	6,160	1,583	370	8,962	11,872	5,482	6,429	(3,977)	10,406
2		9,034	1,583	370	8,962	12,584	5,482	7,151	(904)	8,055
3		8,624	1,583	370	8,962	13,339	5,482	7,906	(344)	8,251
4		8,624	1,583	370	8,962	14,140	5,482	8,707	40	8,667
5		8,624	1,583	370	8,962	14,988	5,402	9,555	447	9,108
6		0	1,583	370	8,962	15,887	5,482	10,454	5,018	5,436
7		0	1,583	370	8,962	15,887	5,482	10,454	5,018	5,436
8		0	1,583	370	8,962	15,887	5,482	10,454	5,018	5,436
9		0	1,583	370	8,962	15,887	5,482	10,454	5,018	5,436
10		0	1,583	370	8,962	15,887	5,482	10,454	5,018	5,436
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20	.	0	1,583	370	8,962	15,887	5,482	10,454	5,018	5,436

Table A.2

CASE 1B: FORD CITY ECONOMIC ANALYSIS

(\$1,000)

Year	Invest	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Steam Rev.	Elect. Rev.	Before Tax Income	Tax	Net Income
1	41,065	6,160	1,583	370	8,962	5,482	11,872	6,439	(4,240)	10,679
2		9,034	1,583	370	9,320	5,701	13,059	7,487	(743)	8,230
3		8,624	1,583	370	9,693	5,929	14,365	8,648	421	8,636
4		8,624	1,583	370	10,081	6,166	15,802	9,934	629	9,305
5		8,624	1,583	370	10,484	6,413	17,382	11,358	1,312	10,046
6		0	1,583	370	10,904	5,670	10,120	12,933	6,208	6,725
7		0	1,583	370	11,340	6,936	19,120	12,763	6,126	6,637
8		0	1,583	370	11,793	7,213	19,120	12,587	6,042	6,545
9		0	1,583	370	12,265	7,502	19,120	12,404	5,954	6,451
10		0	1,583	370	12,755	7,803	19,120	12,215	5,863	6,352
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20	.	0	1,583	370	12,755	7,803	19,120	12,215	5,863	6,352

Table A.3

CASE 1C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Steam Rev.	Elect. Rev.	Before Tax Income	Tax	Net Income
1	41,065	5,133	1,583	370	8,962	5,482	11,872	6,439	627	5,812
2		4,791	1,583	370	9,320	5,701	13,059	7,487	1,294	6,193
3		4,449	1,583	370	9,693	5,929	14,365	8,648	2,016	6,632
4		4,106	1,583	370	10,081	6,166	15,802	9,934	2,797	7,137
5		3,764	1,583	370	10,484	6,413	17,382	11,358	3,645	7,713
6		3,822	1,583	370	10,904	6,670	19,120	12,933	4,565	8,368
7		3,080	1,583	370	11,340	6,936	19,120	12,763	4,648	8,115
8		2,738	1,583	370	11,793	7,213	19,120	12,587	4,728	7,859
9		2,395	1,583	370	12,265	7,502	19,120	12,404	4,804	7,600
10		2,053	1,583	370	12,755	7,803	19,120	12,215	4,878	7,337

Table A.3 (Continued)

CASE 1C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Deprec.	Before Tax Income	Tax	Net Income
11	1,711	12,215	5,042	7,173
12	1,369	12,215	5,206	7,009
13	1,026	12,215	5,371	6,844
14	684	12,215	5,535	6,680
15	342	12,215	5,699	6,516
16	0	12,215	5,863	6,352
17	0	12,215	5,863	6,352
18	0	12,215	5,863	6,352
19	0	12,215	5,863	6,352
20	0	12,215	5,863	6,352

Table A.4

CASE 2A: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Costs	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	27,457	4,119	10,792	11,872	5,482	6,562	(1,574)	8,136
2		6,040	10,792	12,584	5,482	7,274	592	6,682
3		5,766	10,792	13,339	5,482	8,029	1,086	6,943
4		5,766	10,792	14,140	5,482	8,830	1,471	7,359
5		5,766	10,792	14,988	5,482	9,678	1,878	7,800
6		0	10,792	15,887	5,482	10,577	5,077	5,500
7		0	10,792	15,887	5,482	10,577	5,077	5,500
8		0	10,792	15,887	5,482	10,577	5,077	5,500
9		0	10,792	15,887	5,482	10,577	5,077	5,500
10		0	10,792	15,887	5,482	10,577	5,077	5,500
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
20	.	0	10,792	15,887	5,482	10,577	5,077	5,500

Table A.5

CASE 2B: FORD CITY ECONOMIC ANALYSIS

(\$1,000)

Year	Invest.	Deprec.	Oper. Maint. Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	27,457	4,119	1,830	8,962	11,872	5,482	6,562	(1,573)	8,135
2	0	6,040	1,830	9,320	13,059	5,701	7,610	754	6,856
3		5,766	1,830	9,693	14,365	5,929	8,771	1,442	7,329
4		5,766	1,830	10,081	15,802	6,167	10,058	2,060	7,998
5		5,766	1,830	10,484	17,382	6,413	11,481	2,743	8,738
6		0	1,830	10,904	19,120	6,670	13,056	6,267	6,789
7		0	1,830	11,340	19,120	6,937	12,887	6,186	6,701
8		0	1,830	11,794	19,120	7,214	12,710	6,101	6,609
9		0	1,830	12,266	19,120	7,503	12,257	6,013	6,514
10		0	1,830	12,756	19,120	7,803	12,337	5,922	6,415
11	0	0	1,830	13,266	14,120	7,803	12,337	5,827	6,312
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
20	0	0	1,830	13,266	19,120	7,803	12,337	5,827	6,312

Table A.6

CASE 2C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper. & Maint.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	27,457	3,432	1,830	8,962	11,872	5,482	6,562	1,502	5,060
2		3,203	1,830	9,320	13,059	5,701	7,610	2,115	5,495
3		2,975	1,830	9,693	14,365	5,929	8,771	2,782	5,989
4		2,746	1,830	10,081	15,802	6,167	10,058	3,510	6,548
5		2,517	1,830	10,484	17,382	6,413	11,481	4,303	7,178
6		2,288	1,830	10,904	19,120	6,670	13,056	5,169	7,887
7		2,059	1,830	11,340	19,120	6,937	12,887	5,197	7,690
8		1,830	1,830	11,794	19,120	7,214	12,710	5,222	7,488
9		1,602	1,830	12,266	19,120	7,503	12,527	5,244	7,283
10		1,373	1,830	12,756	19,120	7,803	12,337	5,263	7,074

Table A.6 (Continued)

CASE 2C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper. & Maint.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Inc.	Tax	Net Income
11		1,144	1,830	13,266	19,120	8,115	12,139	5,278	6,861
12		915	1,830	13,266	19,120	8,115	12,139	5,300	6,751
13		686	1,830	13,266	19,120	8,115	12,139	5,497	6,642
14		458	1,830	13,266	19,120	8,115	12,139	5,607	6,532
15		229	1,830	13,266	19,120	8,115	12,139	5,717	6,422
16		0	1,830	13,266	19,120	8,115	12,139	5,827	6,312
17	.	.	.	.	.	.	.	.	.
18	.	.	.	.	.	.	.	.	.
19	.	.	.	.	.	.	.	.	.
20	.	0	1,830	13,266	19,120	8,115	12,139	5,827	6,312

Table A.7

CASE 3A: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper. & Maint.	Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	32,656	4,898	1,458	294	8,406	10,932	5,496	6,270	(2,607)	8,877
2		7,184	1,458	294	8,406	11,588	5,496	6,926	(124)	7,050
3		6,858	1,458	294	8,406	12,283	5,496	7,621	366	7,255
4		6,858	1,458	294	8,406	13,020	5,496	8,358	720	7,638
5		6,858	1,458	294	8,406	13,801	5,496	9,139	1,095	8,044
6		0	1,458	294	8,406	14,629	5,496	9,967	4,784	5,182
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20		0	1,458	294	8,406	14,629	5,496	9,967	4,784	5,182

Table A.8

CASE 3B: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	32,656	4,898	1,458	294	8,406	10,932	5,496	6,270	(2,607)	8,877
2		7,184	1,458	294	8,742	12,025	5,701	7,232	23	7,209
3		6,858	1,458	294	9,092	13,228	5,929	8,313	698	7,615
4		6,858	1,458	294	9,456	14,550	6,167	9,509	1,272	8,237
5		6,858	1,458	294	9,334	16,005	6,413	10,832	1,908	8,924
6		0	1,458	294	10,227	17,606	6,670	12,297	5,903	6,394
7		0	1,458	294	10,636	17,606	6,936	12,154	5,834	6,320
8		0	1,458	294	11,062	17,606	7,214	12,006	5,763	6,243
9		0	1,458	294	11,504	17,606	7,502	11,852	5,689	6,163
10		0	1,458	294	11,964	17,606	7,802	11,692	5,612	6,080
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20	.	0	1,458	294	11,964	17,606	7,802	11,692	5,612	6,080

Table A.9

CASE 3C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper. & Maint.	Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	32,656	4,082	1,458	294	8,406	10,932	5,496	6,270	1,050	5,220
2		3,810	1,458	294	8,742	12,025	5,701	7,232	1,643	5,589
3		3,534	1,458	294	9,092	13,228	5,929	8,313	2,294	6,019
4		3,266	1,458	294	9,456	14,550	6,167	9,509	2,997	6,512
5		2,993	1,458	294	9,834	16,005	6,413	10,832	3,763	7,069
6		2,721	1,458	294	10,227	17,606	6,670	12,297	4,596	7,701
7		2,449	1,458	294	10,636	17,606	6,936	12,154	4,658	7,496
8		2,177	1,458	294	11,062	17,606	7,214	12,006	4,718	7,288
9		1,905	1,458	294	11,504	17,606	7,502	11,852	4,775	7,077
10		1,633	1,458	294	11,964	17,606	7,802	11,692	4,828	6,864
11		1,361	1,458	294	11,964	17,606	7,802	11,692	4,959	6,733
12		1,089	1,458	294	11,964	17,606	7,802	11,692	5,089	6,603
13		816	1,458	294	11,964	17,606	7,802	11,692	5,220	6,472
14		544	1,458	294	11,964	17,606	7,802	11,692	5,351	6,341
15		272	1,458	294	11,964	17,606	7,802	11,692	5,482	6,210
16		0	1,458	294	11,964	17,606	7,802	11,692	5,612	6,080
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20	.	0	1,458	294	11,964	17,606	7,802	11,692	5,612	6,080

Table A.10

CASE 4A: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	22,442	3,366	1,458	203	8,406	10,932	5,496	6,361	(806)	7,167
2		4,937	1,458	203	8,406	11,500	5,496	7,015	997	6,078
3		4,713	1,458	203	8,406	12,283	5,496	7,712	1,440	6,272
4		4,713	1,458	203	8,406	13,020	5,496	8,449	1,793	6,656
5		4,713	1,458	203	8,406	13,801	5,496	9,320	2,108	7,062
6		0	1,458	203	8,406	14,629	5,496	10,058	4,828	5,230
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20	.	0	1,458	203	8,406	14,629	5,496	10,058	4,828	5,230

Table A.11

CASE 4B: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Income	Tax	Net Income
1	22,442	3,366	1,458	203	8,406	10,932	5,496	6,361	(816)	7,177
2		4,937	1,458	203	8,742	12,025	5,701	7,323	1,145	6,178
3		4,713	1,458	203	9,092	13,228	5,929	8,404	1,772	6,632
4		4,713	1,458	203	9,456	14,550	6,167	9,600	2,346	7,254
5		4,713	1,458	203	9,834	16,005	6,413	10,923	2,980	7,942
6		0	1,458	203	10,227	17,606	6,670	12,388	5,946	6,442
7		0	1,458	203	10,636	17,606	6,936	12,245	5,878	6,367
8		0	1,458	203	11,062	17,606	7,214	12,097	5,807	6,290
9		0	1,458	203	11,504	17,606	7,502	11,943	5,733	6,210
10		0	1,458	203	11,964	17,606	7,802	11,783	5,656	6,127
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
20	0	0	1,458	203	11,964	17,606	7,802	11,783	5,656	6,127

Table A.12

CASE 4C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Tax & Ins.	Fuel Cost	Elect. Revs.	Steam Revs.	Before Tax Income	Tax	Net Income
1	22,442	2,805	1,458	203	8,406	10,932	5,496	6,361	1,707	4,654
2		2,618	1,458	203	8,742	12,025	5,701	7,323	2,258	5,065
3		2,431	1,458	203	9,092	13,228	5,929	8,404	2,867	5,537
4		2,244	1,458	203	9,456	14,550	6,167	9,600	3,531	6,069
5		2,057	1,458	203	9,834	16,005	6,413	10,923	4,257	6,667
6		1,870	1,458	203	10,227	17,606	6,670	12,388	5,049	7,339
7		1,683	1,458	203	10,636	17,606	6,936	12,245	5,070	7,175
8		1,496	1,458	203	11,062	17,606	7,214	12,097	5,088	7,009
9		1,309	1,458	203	11,504	17,606	7,502	11,943	5,104	6,839
10		1,122	1,458	203	11,964	17,606	7,802	11,783	5,117	6,666

Table A.12 (Continued).

CASE 4C: FORD CITY ECONOMIC ANALYSIS
(\$1,000)

Year	Invest.	Deprec.	Oper & Maint.	Fuel Cost	Elect. Rev.	Steam Rev.	Before Tax Inc.	Tax	Net Income
11		981	1,458	11,964	17,606	7,802	11,783	5,185	6,598
12		785	1,458	11,964	17,606	7,802	11,783	5,279	6,504
13		598	1,458	11,964	17,606	7,802	11,783	5,373	6,410
14		392	1,458	11,964	17,606	7,802	11,783	5,468	6,315
15		196	1,458	11,964	17,606	7,802	11,783	5,562	6,221
16		0	1,458	11,964	17,606	7,802	11,783	5,656	6,127
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
20	.	0	1,458	11,964	17,606	7,802	11,783	5,656	6,127