Industrial Bottoming Cycle Targeting of Opportunities at the Plant Site

Volume 1 - Executive Summary

N. L. Moore, Project Manager

September 1982

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INDUSTRIAL BOTTOMING CYCLE TARGETING
OF OPPORTUNITIES AT THE PLANT SITE

Volume 1 - Executive Summary

N. L. Moore, PNL Project Manager

H. L. Brown

B. B. Hamel

M. P. Toy

B. A. Hedman

General Energy Associates

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Pacific Northwest Laboratory
Richland, Washington 99352

FOREWORD

A study of Industrial Bottoming Cycle Potential (1980-2000), Targeting of Opportunities at the Plant Site (TOPS), was performed by General Energy Associates for the Pacific Northwest Laboratory, operated by Battelle Memorial Institute under contract to the Office of Industrial Programs, Department of Energy. The objective is to provide a data base of potential industrial bottoming cycle applications to stack exhaust; this was developed from individual plant analysis. Whereas previous estimates considered broad industrial sectorial analysis, this study uses the General Energy Associates Industrial Plant Energy Profile (GEA/IPEP) Data Base, which contains process energy information for individual plants.

This document describes the work conducted by General Energy Associates under Pacific Northwest Laboratory Contract B-B4150-A-Z.

The report for this study is contained in four volumes:

<u>Volume Number</u>	<u>Title</u>
PNL-4416 Vol 1	Executive Summary
PNL-4416 Vol 2*	Methodology and Data
PNL-4416 Vol 3*	Industrial Potential Bottoming Cycle Source Book A Geographic - Industrial Sector Profile
PNL-4416 Vol 4*	Industrial Manufacturing Plant Sites

*Volumes 2, 3 and 4 are available from NTIS.

Section 1

Summary

Given the significant increases in energy costs experienced by U. S. industry since 1973, and regulatory relief and incentives in the enactment of the National Energy Act of 1978, bottoming cycles become an option to be considered by industry. The purpose of this study is the identification of bottoming cycle potential in the complex U. S. industrial marketplace using the General Energy Associates Industrial Plant Energy Profile (GEA/IPEP) Data Base. From the data base technology evaluations and economic estimates can be made directly at the plant site level.

Past studies have been characterized by the use of industrial sector models to describe the economics of bottoming cycle technologies. The structure of the U. S. industrial sector is significantly more complex than that afforded by representative plants. The basic premise of the GEA/IPEP Data Base is that, while differences exist in energy use between plants in a given sector, these differences may be quantified by estimating the processes and production levels in each plant. The top 10,000 plants in the country were individually analyzed for these bottoming cycle applications.

The results of this study are summarized below.

Potential Number of Plant Sites and Megawatts.

Based on evaluation of seven working fluids at each plant site, 2521 plant sites produced an uninflated ROI greater than 7%. These plants represent the maximum potential within the scope of this study. These plants correspond to a total of 6393 MW. The table below shows the distribution by industrial groupings.

<u>SIC</u>	<u>Potential Number of Plants</u>		<u>Potential MW</u>	
	(Number)	(%)	(MW)	(%)
28	371	15	880	14
29	224	9	710	11
32	666	26	1528	24
33	537	21	1556	24
34-37	631	25	1546	24
Remaining Sectors	<u>92</u>	4	<u>173</u>	3
	2521		6393	

96% of the plants and 97% of the power (MW) are in these five groupings (SIC 28 - Chemicals; 29 - Refining; 32 - Stone, Clay and Glass; 33 - Primary Metals; 34-37 - Fabricated Metal Products). The 6393 MW are based upon plants with an ROI > 7%; 5500 MW of this total have an ROI > 20%.

These plant sites are presented as a function of system size and are summarized below.

<u>Size (KW)</u>	<u>Total MW Production</u>	<u>%</u>
< 250	5	~ 0
250 - 500	1142	18
500 - 750	1253	20
750 - 1000	512	8
1000 - 1500	1046	16
1500 - 2000	921	14
> 2000	<u>1513</u>	24
	6393	

Potential Energy Savings

Approximately .5 quad of energy are estimated as potential energy savings. This represents the savings at the utility power plant. 97% of this savings occurs in the five major industrial groupings defined above.

Electric Production

Over 45×10^9 Kwh/yr electricity are produced in the potential plants defined above. Approximately 97% of this is developed in the five major groups.

Regional and State Profiles

38% of the potential MW occurs in the sunbelt region (South Atlantic, South West, West). 23% is developed in the Mid Atlantic through New England States. The Mid West region represents the largest region with 28%. Texas has the largest potential in 754 MW or 12% of the total.

Bottoming Cycle/Working Fluid Systems

A comparison of the "best" technology at the plant site with an ROI > 7% indicates that the toluene systems represent 50% of the MW. A comparison of all technologies at a site with an ROI > 7% indicates that the freon and methanol systems represent 30% and the toluene 20%.

\$5.8 billion of equipment and installation costs are represented by the 6393 MW. This reduces to \$4.9 billion for systems with an ROI > 15% and \$2.9 billion for systems with an ROI > 25%. This is based on an accelerated depreciation. A sum-of-the years depreciation reduces this to about 98% of these figures.

Projection of Future Bottoming Cycle Applications

Based on industrial growth figures developed by the Department of Commerce, it is estimated that an additional 5434 MW of bottoming cycle applications may be developed. This assumes that plant expansion and new plant size profiles will be similar to existing plants. Again this figure is based on an ROI > 7%. A profile of this projection as a function of year and ROI is presented in the report.

Section 2

General Methodology

Given the significant increases in energy costs experienced by U.S. industry since 1973 and incentives in the enactment of the National Energy Act in 1978, bottoming cycle applications have become a conservation technology to be considered by industry. Bottoming cycle applications are defined, within the constraints of this study, as the production of electricity from the capture of waste heat from stack exhaust. The evaluation of bottoming cycle applications in U.S. industry has been the subject of a number of studies with primary emphasis on technology evaluations and broad sector analysis.

The present study, offers a unique approach to the identification of technology potential in the complex U.S. industrial energy marketplace. By using a plant specific data base, technology and economic estimates can be made directly at the plant site level. The economics depend critically on the individual plant waste energy, hours of operations and utility rates.

The basic approach in this study has been to use a data base at the plant level for all large U.S. industrial plants, with appropriate field verification, to serve as the starting point for the technical/economic analysis of bottoming cycle viability. The approach has the obvious advantage of avoiding the use of representative plants and utility rates - but rather using actual plant sites with the appropriate utility costs.

The basic methodology for the study is outlined in Exhibit 1. The plant data base used is the GEA/IPEP* plant data base. This data base contains detailed plant estimates of waste energy, electricity use, and hours of operation for the top 10,000 U.S. industrial plants. Each plant is identified in the data file by name, address, SIC, products and electric

*The General Energy Associates Industrial Plant Energy Profile (GEA/IPEP) Data Base is described in Section 2.

utility (Exhibits 2, 3 and 4). Use of plant level estimates allows the application of detailed economic calculations for each individual plant. Those plants that pass some minimum plant economic return on investment become potential sites. Rather than attempting to determine the acceptability of certain ROI's to various industrial sectors, the basic data on ROI distributions are presented and the users of this study can apply their own criteria for penetration of this potential.

Detailed, computer based descriptions of seven working fluid technologies (Exhibit 5) are used to obtain a preliminary design of each bottoming cycle system in a plant setting. This design sizes the system for the plant based on the stack exhaust and produces a capital cost estimate for the system. This capital cost is then an input to the economic model which accounts for all cash streams over the life of the equipment. All relevant factors are considered in generating the cash streams. Actual utility costs are used for the plant. The plant estimates of waste energy, electric use, and hours of operation are used to calculate the appropriate cash streams and return on investment (ROI) for the technologies. A computer flow diagram of the methodology is presented in Exhibit 6.

This methodology produces a list of potential sites that have passed the minimum ROI filter. This then represents those plants that can potentially make use of one of the bottoming cycle systems listed in Exhibit 5. These are presented in detail in Volumes 3 and 4.

To project this potential to the year 2000, industrial projections have been developed and are based upon a projection methodology presented in Exhibit 7. This methodology produces estimates for each sector with the basic assumption that the plant size distribution and energy use characteristics of those new sites that will be added are similar to the existing plant stock.

Exhibit 1

METHODOLOGY

Exhibit 2

GENERAL INDUSTRIAL DATA BASE APPROACH

FOR

TOP 10,000 U.S.A. PLANTS

Identification of Plant
Site Name and Address
by Industrial Sector

Identification of Generic
Plant Types for Given
Industrial Sector

Verification and
Validation

Dun & Bradstreet Plant
List, State Directories,
Trade Associations

108 Drexel Process Data
Base and GEA Process
Data Base

International Cogeneration
Society Utility Review:
Utility and Industrial

Sort Industrial Plants
and Assign Generic Type
and Production Levels

Energy Use
Per
Unit Product

Trade Association Data
Sources

Plant Estimates of Waste
Energy, Temperature and
Electricity Use and Energy
Costs

Validated Plant
Site Estimates

∞

Exhibit 3

INDUSTRIAL DATA BASE APPROACH: EXAMPLE

Below is shown in summary fashion the data base methodology for a sample industry: steel.

3312 - BLAST FURNACES AND STEEL MILLS

Exhibit 5

Bottoming Cycle/Stack Exhaust Application

Rankine System

Working Fluids

- Freon R11
- Freon R113
- Methanol
- Fluorinol 85
- 2 - Methyl Pyridine/H₂O
- Toluene
- Water

Exhibit 6

ROI Model

Exhibit 7

PROJECTION METHODOLOGY

GROWTH PROJECTION

INCREMENT OF GROWTH PER YEAR

% Compound Growth Rate
Per Annum by 2 Digit SIC

Sources:

Commerce Dept. Outlook
1980-1985
Chemical Engineering

% Growth is Used With
Existing MW Capacity
by 2 Digit SIC and State
to Predict Growth
increment in M.W.

BOTTOMING CYCLE POTENTIAL
FACTOR

From Potential Bottoming
Cycle Application

Bottoming Cycle
(MW) Potential
(MW) Installed Capacity
For Each 2 Digit SIC

PROJECTED BOTTOMING CYCLE
POTENTIAL GROWTH

Growth Increment in Bottom-
ing Cycle Potential by
Industrial Sector

Section 3

GEA/IPEP Plant Site Data Base

It is clear that the major and unique contribution of this study is the application of actual U.S. plant sites to the broad range of technology and economic models for bottoming cycle, applications. Because of this, a detailed description of the methodology in the construction of the GEA/IPEP Data Base for the top 10,000 plants used in the study is presented.

The basic premise used to construct the data base is that, while differences exist in energy use between plants in a given industrial sector - these differences may be quantified by estimating the processes and production levels in each plant. Plants with common processes may be grouped into generic plant types (Exhibit 8). For these generic plant types, a process data base is used to estimate the processes and energy use per unit product for that generic plant. Key to this is the ability to recognize and, classify each actual plant into a generic plant type and to determine production levels for the plant. Trade association data sources are used. So that central to the success of this approach are three key data bases (Exhibit 2).

- An accurate list of plants by industrial sector: the Dun and Bradstreet plant list, state directories, and trade association plant sites.
- A process data base to establish generic plant types and energy intensity: the Drexel 108 Process Data Base with the addition of significant number of processes by GEA.
- A method for classifying actual plants by generic type and production level by plant: trade association sources (see Appendix A of Volume II).

It is clear that two plants in the same generic type may differ in their energy intensity per unit product owing to age of equipment, efficiency of overall plant operation and percent capacity of plant production.

Because of these factors, estimates will deviate from actual plant operation. In order to account for this, field verification and validation of plant estimates was conducted by the International Cogeneration Society (ICS). Plants were organized by electric utility and these lists were reviewed by the ICS staff in conjunction with utility personnel. Quantities reviewed were:

- Plant demand, KW
- Plant electric use (Kwh)
- Plant steam use
- Plant operation, hours/year
- Utility electric rate

From this information and other data, estimates of stack energy flow were possible. This has contributed to the use of a very broad and reasonable set of plant estimates in the technology/ROI models for estimation of bottoming cycle potential.

In order to focus on the key elements in the methodology, the steel plants in New York State are developed as an example in Volume II.

Exhibit 8

GENERIC PLANT TYPES

<u>SECTOR</u>	<u>PLANT TYPES</u>	<u>REMARKS AND REFERENCES</u>
Food (SIC 20)	Relevant Six Digit SIC was used to create Generic Plant Types	
Textiles (SIC 22)	10 Generic Types	Each plant is placed in relevant category
Wood Products (SIC 24)	10 Product Types	Plants are then built using these products - each plant individually modeled
Paper (SIC 26)	7 process types with: % bleaching % cogeneration % integration from wood to paper	Plants classified by process, with the appropriate process variables used for each plant
Chemicals (SIC 28)	250 Individual Chemicals	Each plant is built up from the relevant chemicals in the process data base
Petrorefining (SIC 29)	10 Processes	Each refinery is built from bbl processed by each unit operation
Plastics and Rubber (SIC 30)	Relevant 4 Digit SIC used for each plant. Plant employment used to scale	Employment and 4 Digit SIC taken from References
Stone/Clay/Glass (SIC 32)	Relevant 4 Digit SIC used for each plant. Plant employment used to scale relevant process energy	
Steel (SIC 331)	9 Generic Types	Plants classified
Primary Metals (SIC 33) other than steel and Metals (SIC 34-39)	Six Digit SIC used to create generic plants. Plant employment used to scale relevant process energies	

Section 4

Potential Bottoming Cycle-Stack Application

The details of the results of the study of bottoming cycle/stack applications by state are presented in Volume 3. Potential plants are defined as those existing industrial plant sites for which economic analysis of all bottoming cycle/working fluid technologies produces at least one system with an ROI greater than 7%. Potential power production (MW) represents the power level associated with the "best" technology at the potential plant. The "best" technology is defined at the plant site as that system which has the largest ROI greater than 7%. If analysis indicates that no bottoming cycle system has an ROI greater than 7%, then it is not classified as potential and is not included in the study. The following elements of potential bottoming cycle applications are summarized in this section:

- Number of Plants
- Power Generation (MW)
- Energy Savings (BTU/yr)
- Electric Production (Kwh/yr)
- Regional Profiles
- State Profiles
- Bottom Cycle/Working Fluid Systems
- Projection of Future Bottoming Cycle Applications

These are examined as a function of industrial sector, system size and ROI. The industrial sectors are reviewed in Appendix A. A correlation between a 1980 constant dollar (uninflated) ROI and the inflated ROI is presented in Appendix B. All ROI presented in the report are in constant 1980 dollars. The primary analysis was conducted with accelerated depreciation (Appendix C).

Number of Potential Cogeneration Plants

The number of potential industrial plant sites which have a best bottoming cycle application (ROI > 7%) is 2521. These results are presented in Exhibits 9 through 13 and are summarized below:

<u>SIC</u>	<u>Number of Potential Plant Sites</u>	<u>%</u>
28	371	15
29	224	9
32	666	26
33	537	21
34-37	631	25
Remaining Sectors	<u>92</u>	4
	2521	

These figures represent the numbers and percentage of plants. The distribution of power production (MW) is discussed below.

96% of the plants are in five industrial groupings (28-Chemicals; 29-Refining; 32-Stone, Clay and Glass; 33-Primary Metals; 34-37-Fabricated Metal Products). 41% of the plants have "best" systems with ROI > 7% in the 250-500 KW size range and 59% of the plants have "best" system sizes greater than 500 KW.

The primary results of this analysis was conducted with an accelerated depreciation. However, a comparison analysis was conducted with Sum-of-the-Years (SOY) depreciation. As shown in Exhibit 11, the SOY method produces only 2454 potential plants or approximately 97% of the number of potential plants using the accelerated depreciation. Approximately 75% of the plants have an ROI greater than 15%.

Power Generation (MW)

The total power generation from these potential plants (ROI > 7%) is 6393 MW. These results are presented in Exhibits 14 through 18. A summary of the distribution by industrial sector is presented below (accelerated depreciation). An ROI analysis using SOY depreciation develops a total power generation of 6350 MW or approximately 99% of that developed using the accelerated depreciation schedule (Appendix C).

<u>SIC</u>	<u>Potential Power Production (MW)</u>	<u>%</u>
28	880	14
29	710	11
32	1528	24
33	1556	24
34-37	1546	24
Remaining Sectors	<u>173</u>	3
	6393	

In this analysis these five industrial groupings represent 97% of the total power production and these same five groups represent 96% of the potential plants. Over 5500 MW or approximately 85% of the MW production shows an ROI > 20% in Exhibit 15.

The distribution of total power production by system size indicates that approximately 54% of the power production occurs in systems greater than 1.0 MW while there are only 30% of the plants in this size range. A distribution of system size is presented below:

<u>System Size (KW)</u>	<u>Total MW Production</u>	<u>MW %</u>	<u>Number of Plants</u>	<u>Plants %</u>
< 250	5	~ 0	5	~ 0
250 - 500	1142	18	1023	41
500 - 750	1253	20	518	21
750 - 1000	512	8	204	8
1000 - 1500	1046	16	325	13
1500 - 2000	921	14	213	8
> 2000	<u>1513</u>	24	<u>233</u>	9
	6393		2521	

Energy Savings (BTU/yr)

Results of energy savings are presented in Exhibits 19, 20 and 21. A summary is presented below for potential plants with the "best" technology having an ROI > 7%.

<u>SIC</u>	<u>Energy Savings (10¹² BTU/yr)</u>	<u>%</u>
28	77	15
29	68	13
32	116	22
33	120	23
34-37	124	24
Remaining Sectors	<u>13</u>	3
	518	

These energy savings represent those at the utility (assuming a utility efficiency of 33%). 97% of the energy savings occurs in these five industrial groupings. Approximately 75% of this savings occurs in systems having an ROI > 20%.

Electric Production (Kwh/yr).

Over 45×10^9 Kwh/yr are generated in these potential bottoming cycle systems (ROI > 7%). These results are presented in Exhibits 22 and 23. 97% is generated within these five groups.

Regional Profiles

A regional (Appendix E) summary of bottoming cycle potential ($ROI > 7\%$) is presented in Exhibit 24. 38% of the MW generation occurs in the Sun Belt Region (South Atlantic, South West and West). 23% of the MW is developed in the Mid-Atlantic through New England States. The Mid West (Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota) represents the largest region with 28% of the power production; it represents 29% of the plants.

State Profiles

A summary of the state bottoming cycle potential is presented in Exhibit 25 for systems with $ROI > 7\%$. These are presented in alphabetical order. Texas has the largest number of plants with 210 (8%) and the largest power generation at 754 MW (12%).

Bottoming Cycle/Working Fluid Systems

A comparison of the "best" technologies at the plant site with an $ROI > 7\%$ indicates that the Freon or Methanol systems are not represented. The Toluene system is most significant at 50%.

In comparison, if all technologies with an $ROI > 7\%$ are considered (that is a single plant may have a number of systems with an $ROI > 7\%$), the distribution is modified as shown in Exhibit 26. Now the Freon and Methanol systems represent 36% and the Toluene 20%.

An analysis of these "best" systems indicates that \$5.8 billion of equipment and installation costs are represented by these potential systems with an $ROI > 7\%$. This reduces to \$4.9 billion for "best" systems with an $ROI > 15\%$. SOY depreciation analysis reduces this to approximately 98% of these figures.

These figures represent an average installed cost of approximately \$907 per KW in 1980 dollars.

Projection of Future Bottoming Cycle Applications.

A projection of industrial bottoming cycle applications is based on the industrial growth figures presented in Appendix D as developed primarily by the Commerce Department's Industrial Outlook, 1980-1985. The methodology is presented in detail in Volume 2. As indicated earlier, the potential bottoming cycle applications previously presented includes analysis of only those plants currently in existence at their production levels. Since industrial growth is based on expansion and new plants, it is assumed here that the ratio of potential bottoming cycle applications to the total plant demand for each sector will apply to industrial growth (expansion plus new plants). This ratio is applied to this new industrial capacity which is determined by compounding the growth figures (Appendix D). This assumes basically that new industrial capacity will have a plant size distribution similar to that which currently exists. Using these assumptions there is a projected bottoming cycle application above the potential 6393 MW of 5434 MW with an ROI > 7%. This says that in 20 years there will be an additional potential of 5434 MW with an ROI > 7%. These results are presented in Exhibit 27.

Exhibit 9

FINAL SOURCE BOOK

POTENTIAL BOTTOMING CYCLE ANALYSIS: NATIONAL TOTALS

NUMBER OF POTENTIAL PLANTS
(ROI > 7%)

BIC	BOTTOMING SYSTEM UNIT SIZE									TOTAL
	0.0<KW<250	250<KW<500	500<KW<750	750<KW<1000	1.0<MW<1.5	1.5<MW<2.0	2.0<MW<5.0	5.0<MW<10.	MW>10.	
20	0	13	2	0	0	0	0	0	0	15
21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
26	4	54	10	2	0	0	0	0	0	70
27	0	0	0	0	0	0	0	0	0	0
28	0	75	46	17	88	78	67	0	0	371
29	0	55	97	18	50	4	0	0	0	224
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0
32	0	236	122	81	68	52	90	16	1	666
33	0	176	97	40	94	75	50	3	2	537
34	0	73	24	15	7	0	2	0	0	121
35	0	71	24	7	5	1	0	0	0	108
36	1	104	20	5	4	1	1	0	0	136
37	0	160	76	18	9	2	1	0	0	266
38	0	6	0	1	0	0	0	0	0	7
39	0	0	0	0	0	0	0	0	0	0
TOTAL	5	1023	518	204	325	213	211	19	3	2521

POTENTIAL PLANT SITES WITH BOTTOMING CYCLE-APPLICATIONS

Exhibit 11

Number of Potential Bottoming Cycle Plants

Exhibit 12

NUMBER OF POTENTIAL PLANTS WITH BOTTOMING CYCLE APPLICATIONS

Exhibit 13

Exhibit 14

FINAL SOURCE BOOK

POTENTIAL BOTTOMING CYCLE ANALYSIS: NATIONAL TOTALS

TOTAL POTENTIAL POWER GENERATION(MW)
(ROI > 7%)

SIC	BOTTOMING SYSTEM UNIT SIZE									TOTAL
	0.0<KW<250	250<KW<500	500<KW<750	750<KW<1000	1.0<MW<1.5	1.5<MW<2.0	2.0<MW<5.0	5.0<MW<10.	MW>10.	
20	0.	22.	6.	0.	0.	0.	0.	0.	0.	28.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	4.	85.	29.	9.	0.	0.	0.	0.	0.	127.
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	33.	33.	20.	163.	279.	352.	0.	0.	880.
29	0.	30.	397.	31.	246.	6.	0.	0.	0.	710.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	172.	154.	150.	187.	210.	503.	138.	13.	1528.
33	0.	125.	192.	115.	288.	377.	376.	37.	45.	1556.
34	0.	73.	41.	25.	18.	0.	13.	0.	0.	170.
35	0.	117.	79.	36.	40.	13.	0.	0.	0.	285.
36	1.	173.	63.	25.	31.	10.	20.	0.	0.	323.
37	0.	300.	258.	95.	73.	26.	16.	0.	0.	768.
38	0.	11.	0.	7.	0.	0.	0.	0.	0.	18.
39	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	5.	1142.	1253.	512.	1046.	921.	1280.	175.	58.	6393.

Exhibit 15

POTENTIAL BOTTOMING CYCLE POWER PRODUCTION (MW)

MW of Potential Bottoming Cycle
Generation Greater than Specified ROI

Potential Bottoming Cycle Power Generation (MW)

Exhibit 18

Potential Bottoming Cycle Power Generation

Exhibit 19

FINAL SOURCE BOOK

POTENTIAL BOTTOMING CYCLE ANALYSIS: NATIONAL TOTALS

POTENTIAL ENERGY SAVINGS (10*9 BTU/YR)

(ROI > 7%)

BIC	BOTTOMING SYSTEM UNIT SIZE									TOTAL
	0.0<KW<250	250<KW<500	500<KW<750	750<KW<1000	1.0<MW<1.5	1.5<MW<2.0	2.0<MW<5.0	5.0<MW<10.	MW>10.	
20	0.	820.	137.	0.	0.	0.	0.	0.	0.	958.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	328.	7311.	2060.	514.	0.	0.	0.	0.	0.	10214.
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	2734.	2484.	1668.	13955.	24703.	31010.	0.	0.	76552.
29	0.	2712.	38206.	2972.	23909.	604.	0.	0.	0.	68403.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	9145.	9098.	10132.	13084.	17292.	44135.	12183.	1040.	116106.
33	0.	7472.	11666.	7681.	22469.	30966.	31981.	3578.	4280.	120090.
34	0.	3683.	1935.	1655.	1714.	0.	1214.	0.	0.	10201.
35	0.	10745.	7607.	3517.	3841.	1248.	0.	0.	0.	26958.
36	52.	10727.	5174.	1613.	2381.	472.	564.	0.	0.	20985.
37	0.	21919.	23809.	9145.	7041.	2528.	1592.	0.	0.	66034.
38	0.	957.	0.	629.	0.	0.	0.	0.	0.	1585.
39	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	380.	78226.	102177.	39527.	88394.	77813.	110495.	15761.	5320.	518085.

Potential Bottoming Cycle Energy Savings
In Industrial Manufacturing Sector

Exhibit 21

POTENTIAL BOTTOMING CYCLE ENERGY SAVINGS (10^{12} Btu/yr)

Exhibit 22

FINAL SOURCE BOOK

POTENTIAL BOTTOMING CYCLE ANALYSIS: NATIONAL TOTALS

POTENTIAL ELECTRIC GENERATION(10% KWH/YR)

(ROI > 7%)

BIC	BOTTOMING SYSTEM UNIT SIZE									TOTAL
	0.0<KW<250	250<KW<500	500<KW<750	750<KW<1000	1.0<MW<1.5	1.5<MW<2.0	2.0<MW<5.0	5.0<MW<10.	MW>10.	
20	0.	72.	12.	0.	0.	0.	0.	0.	0.	84.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	29.	643.	181.	45.	0.	0.	0.	0.	0.	898.
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	240.	218.	147.	1226.	2172.	2727.	0.	0.	6731.
29	0.	238.	3359.	261.	2103.	53.	0.	0.	0.	6014.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	804.	800.	891.	1149.	1520.	3880.	1071.	92.	10207.
33	0.	657.	1026.	675.	1977.	2721.	2812.	315.	378.	10560.
34	0.	324.	170.	145.	151.	0.	107.	0.	0.	897.
35	0.	945.	669.	309.	339.	109.	0.	0.	0.	2371.
36	5.	944.	455.	142.	210.	41.	50.	0.	0.	1846.
37	0.	1927.	2093.	804.	619.	222.	140.	0.	0.	5805.
38	0.	84.	0.	55.	0.	0.	0.	0.	0.	139.
39	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	33.	6878.	8983.	3475.	7773.	6839.	9715.	1386.	470.	45553.

Potential Bottoming Cycle Generation of
Electricity in Industrial Manufacturing Sector

Exhibit 24

REGIONAL SUMMARY OF POTENTIAL BOTTOMING CYCLES

REGION	NUMBER OF POTENTIAL PLANTS	POTENTIAL POWER GENERATION (MW)	POTENTIAL ELECTRICITY GENERATION (10*6 KWH/YR)	POTENTIAL ENERGY SAVINGS (10*6 BTU/YR)
NEW ENGLAND	74	172	1105	12568
NY/NJ	155	346	2458	27958
MID ATLANTIC	368	924	6305	71715
SOUTH ATLANTIC	323	613	4103	46664
MID WEST	720	1786	12405	141106
SOUTH WEST	381	1231	9605	109243
CENTRAL	190	474	3442	39135
NORTH CENTRAL	57	159	1203	13665
WEST	199	555	3982	45312
NORTH WEST	52	125	942	10724
TOTALS	2521	6392	45553	518094

*
BEST SYSTEM AT PLANT SITE
ACCELERATED DEPRECIATION
ROI > 7%

Exhibit 25

STATE SUMMARY OF POTENTIAL BOTTOMING CYCLES

STATE	NUMBER OF POTENTIAL PLANTS	POTENTIAL POWER GENERATION	POTENTIAL ELECTRICITY GENERATION	POTENTIAL ENERGY SAVINGS
		(MW)	(10 ⁶ KWH/YR)	(10 ⁶ BTU/YR)
ALABAMA	84	150	964	10964
ALASKA	2	8	71	818
ARIZONA	20	87	598	6797
ARKANSAS	29	53	349	3977
CALIFORNIA	166	445	3236	36829
COLORADO	21	39	282	3209
CONNECTICUT	34	88	593	6742
DELAWARE	12	30	237	2698
DIST OF COLUMBIA	0	0	0	0
FLORIDA	40	81	563	6408
GEORGIA	51	95	655	7460
HAWAII	7	12	85	976
IDAHO	5	7	60	688
ILLINOIS	169	476	3354	38172
INDIANA	107	260	1885	21438
IOWA	47	116	868	9873
KANSAS	36	78	591	6730
KENTUCKY	39	86	564	6417
LOUISIANA	89	323	2587	29423
MAINE	9	15	109	1239
MARYLAND	28	69	475	5402
MASSACHUSETTS	22	53	319	3639
MICHIGAN	156	409	2906	33053
MINNESOTA	20	32	194	2210
MISSISSIPPI	25	49	361	4110
MISSOURI	54	171	1267	14413
MONTANA	6	26	184	2094
NEBRASKA	14	22	149	1701
NEVADA	6	11	62	708
NEW HAMPSHIRE	2	2	21	244

*
BEST SYSTEM AT PLANT SITE
ACCELERATED DEPRECIATION
ROI > 7%

Exhibit 25 (Continued)

STATE SUMMARY OF POTENTIAL BOTTOMING CYCLES *

STATE	NUMBER OF POTENTIAL PLANTS	POTENTIAL POWER GENERATION (MW)	POTENTIAL ELECTRICITY GENERATION (10*6 KWH/YR)	POTENTIAL ENERGY SAVINGS (10*6 BTU/YR)
NEW JERSEY	70	139	947	10775
NEW MEXICO	11	14	97	1105
NEW YORK	85	207	1510	17182
NORTH CAROLINA	47	64	401	4564
NORTH DAKOTA	2	2	18	215
OHIO	213	499	3298	37504
OKLAHOMA	42	86	647	7357
OREGON	15	30	191	2176
PENNSYLVANIA	243	660	4498	51168
RHODE ISLAND	7	9	47	536
SOUTH CAROLINA	37	84	564	6413
SOUTH DAKOTA	1	3	30	344
TENNESSEE	39	86	593	6743
TEXAS	210	754	5923	67379
UTAH	18	76	595	6755
VERMONT	2	2	14	166
VIRGINIA	42	78	493	5607
WASHINGTON	30	79	619	7041
WEST VIRGINIA	43	87	601	6839
WISCONSIN	55	109	767	8729
WYOMING	9	11	92	1047
TOTALS	2521	6392	45553	518094

*
BEST SYSTEM AT PLANT SITE
ACCELERATED DEPRECIATION
ROI > 7%

Exhibit 26

WORKING FLUID COMPARISONS

Percentage Distribution of Potential
Bottoming Cycle Capacity (MW)

<u>Working Fluid</u>	<u>Best System at Site</u>	<u>All Systems</u>
1 Freon R11	0	12
2 Freon R113	0	14
3 Methanol	~ 0	10
4 Fluorinol 85	20	17
5 2-Methyl Pyridine/H ₂ O	27	11
6 Toluene	50	20
7 Water	3	16

Exhibit 27

Projected Bottoming Cycle Power Generation

Appendix A. Industrial Sector Definition

SIC Definition

<u>SIC</u>	<u>Description</u>
20	Food
21	Tobacco Products
22	Textile Mill Products
23	Apparel
24	Lumber and Wood Products
25	Furniture and Fixtures
26	Paper
27	Printing and Publishing
28	Chemicals
29	Petroleum and Coal Products
30	Rubber, Misc. Plastic Products
31	Leather
32	Stone, Clay and Glass Products
33	Primary Metals
34	Fabricated Metal Products
35	Machinery, Except Elect.
36	Electric and Electronic Equip.
37	Transportation Equipment
38	Instruments and Related Products
39	Misc. Manufacturing

Appendix B, ROI Correlation

INFLATED ROI (%) AS A FUNCTION OF INFLATION

UNINFLATED ROI (%/YR)	INFLATION IN %/YR					
	6 %	8 %	10%	12%	14%	16%
1.0	7.1	9.1	11.1	13.1	15.1	17.2
2.0	8.1	10.2	12.2	14.2	16.3	18.3
3.0	9.2	11.2	13.3	15.4	17.4	19.5
4.0	10.2	12.3	14.4	16.5	18.6	20.6
5.0	11.3	13.4	15.5	17.6	19.7	21.8
6.0	12.4	14.5	16.6	18.7	20.8	23.0
7.0	13.4	15.6	17.7	19.8	22.0	24.1
8.0	14.5	16.6	18.8	21.0	23.1	25.3
9.0	15.5	17.7	19.9	22.1	24.3	26.4
10.0	16.6	18.8	21.0	23.2	25.4	27.6
11.0	17.7	19.9	22.1	24.3	26.5	28.8
12.0	18.7	21.0	23.2	25.4	27.7	29.9
13.0	19.8	22.0	24.3	26.6	28.8	31.1
14.0	20.8	23.1	25.4	27.7	30.0	32.2
15.0	21.9	24.2	26.5	28.8	31.1	33.4
16.0	23.0	25.3	27.6	29.9	32.2	34.6
17.0	24.0	26.4	28.7	31.0	33.4	35.7
18.0	25.1	27.4	29.8	32.2	34.5	36.9
19.0	26.1	28.5	30.9	33.3	35.7	38.0
20.0	27.2	29.6	32.0	34.4	36.8	39.2
21.0	28.3	30.7	33.1	35.5	37.9	40.4
22.0	29.3	31.8	34.2	36.6	39.1	41.5
23.0	30.4	32.8	35.3	37.8	40.2	42.7
24.0	31.4	33.9	36.4	38.9	41.4	43.8
25.0	32.5	35.0	37.5	40.0	42.5	45.0

Appendix C

Accelerated Depreciation Schedule

<u>Year</u>	<u>Depreciation (%)</u> <u>Equipment</u>	<u>Structures</u>
1	15	12
2	22	10
3	21	9
4	21	8
5	21	7
6		6
7		6
8		6
9		6
10		5
11		5
12		5
13		5
14		5
15		5

Appendix D

INDUSTRIAL GROWTH PROJECTIONS

<u>SIC</u>	<u>Growth (%/Year)</u>
20	1.7
21	0
22	1.4
23	1.4
24	5.9
25	4.1
26	3.4
27	2.0
28	4.2
29	2.5
30	3.2
31	2.0
32	2.9
33	1.8
34	2.5
35	4.0
36	7.1
37	2.3
38	6.0
39	2.5

Appendix E
EIA/DOE REGIONS

Regions:

1. New England
2. NY/NJ
3. MID Atlantic
4. South Atlantic
5. MID West
6. South West
7. Central
8. North Central
9. West
10. North West

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